SBAS154C – OCTOBER 2000 – REVISED OCTOBER 2002

# 14-Bit, 10MSPS Self-Calibrating ANALOG-TO-DIGITAL CONVERTER

## FEATURES

- SELF-CALIBRATING
- HIGH SFDR: 85dB at NYQUIST
- HIGH SNR: 76dB
- LOW POWER: 250mW
- DIFFERENTIAL OR SINGLE-ENDED INPUTS
- +3V/+5V LOGIC I/O COMPATIBLE
- FLEXIBLE INPUT RANGE
- OVER-RANGE INDICATOR
- INTERNAL OR EXTERNAL REFERENCE

## APPLICATIONS

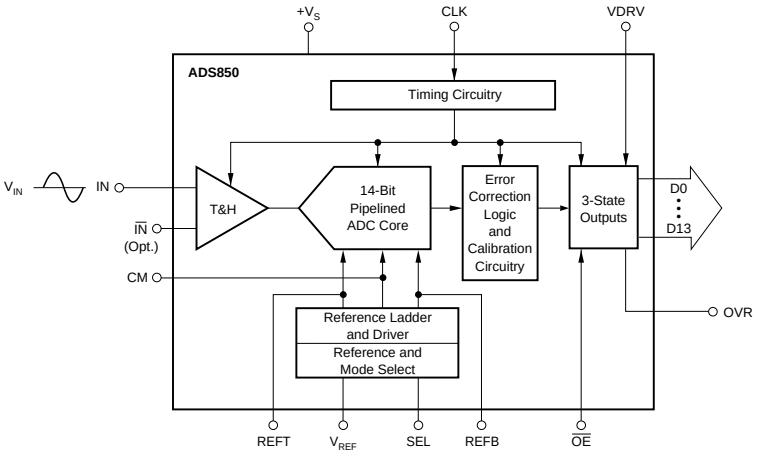
- IF AND BASEBAND DIGITIZATION
- CCD IMAGING SCANNERS
- TEST INSTRUMENTATION
- IR IMAGING

## DESCRIPTION

The ADS850 is a high dynamic range, 14-bit Analog-to-Digital Converter (ADC) that utilizes a fully differential input, allowing for either single-ended or differential input interface over varying input spans. This converter features digital error correction techniques ensuring 14-bit linearity and a calibration procedure that corrects for capacitor and gain mismatches. The ADS850 also includes a high-bandwidth track-and-hold that provides excellent spurious performance up to and beyond the Nyquist rate.

The ADS850 provides an internal reference that can be programmed for a 2Vp-p input range for the best spurious performance and ease of driving. Alternatively, the 4Vp-p input range can be used for the lowest input referred noise, offering superior signal-to-noise performance for imaging applications. There is also the capability to set the range between 2Vp-p and 4Vp-p, or to use an external reference. The ADS850 also provides an over-range indicator flag to indicate if the input has exceeded the full-scale input range of the converter.

The low distortion and high signal-to-noise performance provide the extra margin needed for communications, imaging, and test instrumentation applications. The ADS850 is available in a TQFP-48 package.




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.

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.

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## ABSOLUTE MAXIMUM RATINGS[1]

| | |
|---|---|
| $+V_S$ | +6V |
| Analog Input | (–0.3V) to ($+V_S$ +0.3V) |
| Logic Input | (–0.3V) to ($+V_S$ +0.3V) |
| Case Temperature | +100°C |
| Junction Temperature | +150°C |
| Storage Temperature | +150°C |

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

## DEMO BOARD ORDERING INFORMATION

| PRODUCT | DEMO BOARD |
|---|---|
| ADS850Y | ADS850Y-EVM |

## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## PACKAGE/ORDERING INFORMATION

| PRODUCT | PACKAGE-LEAD | PACKAGE DESIGNATOR[1] | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|---|---|---|---|---|---|---|
| ADS850Y | TQFP-48 | PFB | –40°C to +85°C | ADS850Y | ADS850Y/250 | Tape and Reel, 250 |
| " | " | " | " | " | ADS850Y/2K | Tape and Reel, 2000 |

NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

# ELECTRICAL CHARACTERISTICS

At $T_A$ = full specified temperature range, $V_S$ = +5V, specified differential input range = 1.5V to 3.5V, internal reference input, sampling rate = 10MSPS after calibration, and $V_{REF}$ = 2V, unless otherwise specified.

| | | ADS850Y | | | |
|---|---|---|---|---|---|
| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
| **RESOLUTION** | | | 14 | | Bits |
| **SPECIFIED TEMPERATURE RANGE** | | | –40 to +85 | | °C |
| **CONVERSION CHARACTERISTICS** | | | | | |
| Sample Rate | | 10k | | 10M | Samples/s |
| Data Latency | | | 7 | | Clk Cycles |
| **ANALOG INPUT** | | | | | |
| Single-Ended Input Range | $V_{REF}$ = 1.0 | 1.5 | | 3.5 | V |
| | $V_{REF}$ = 2.0 | 0.5 | | 4.5 | V |
| Differential Input Range | $V_{REF}$ = 2.0 | 1.5 | | 3.5 | V |
| Common-Mode Voltage | | | 2.5 | | V |
| | | | 1 | | V |
| Input Capacitance | | | 20 | | pF |
| Analog Input Bandwidth | –3dBFS Input | | 270 | | MHz |
| **DYNAMIC CHARACTERISTICS** | | | | | |
| Differential Linearity Error (Largest Code Error) | | | | | |
| f = 4.8MHz | | | ±0.75 | ±1.0 | LSB |
| No Missing Codes | | | Tested | | |
| Spurious-Free Dynamic Range[1] | | | | | |
| f = 4.8MHz (–1dB input) | 4Vp-p | 75 | 85 | | dBFS[2] |
| f = 4.8MHz (–1dB input) | 2Vp-p | | 82 | | dBFS |
| Signal-to-Noise Ratio (SNR) | | | | | |
| f = 4.8MHz (–1dB input) | 4Vp-p | 71 | 76 | | dBFS |
| f = 4.8MHz (–1dB input) | 2Vp-p | | 73 | | dBFS |
| Signal-to-(Noise + Distortion) (SINAD) | | | | | |
| f = 4.8MHz (–1dB input) | 4Vp-p | 70 | 75 | | dBFS |
| f = 4.8MHz (–1dB input) | 2Vp-p | | 72 | | dBFS |
| Effective Number of Bits at 4.8MHz[3] | | | 12.2 | | Bits |
| Integral Nonlinearity Error | | | | | |
| f = 4.8MHz | | | ±2.5 | ±5.0 | LSB |
| Aperture Delay Time | | | 1 | | ns |
| Aperture Jitter | | | 4 | | ps rms |
| Overvoltage Recovery Time | 1.5 • FS Input | | 2 | | ns |
| Full-Scale Step Acquisition Time | | | 50 | | ns |

# ELECTRICAL CHARACTERISTICS (Cont.)

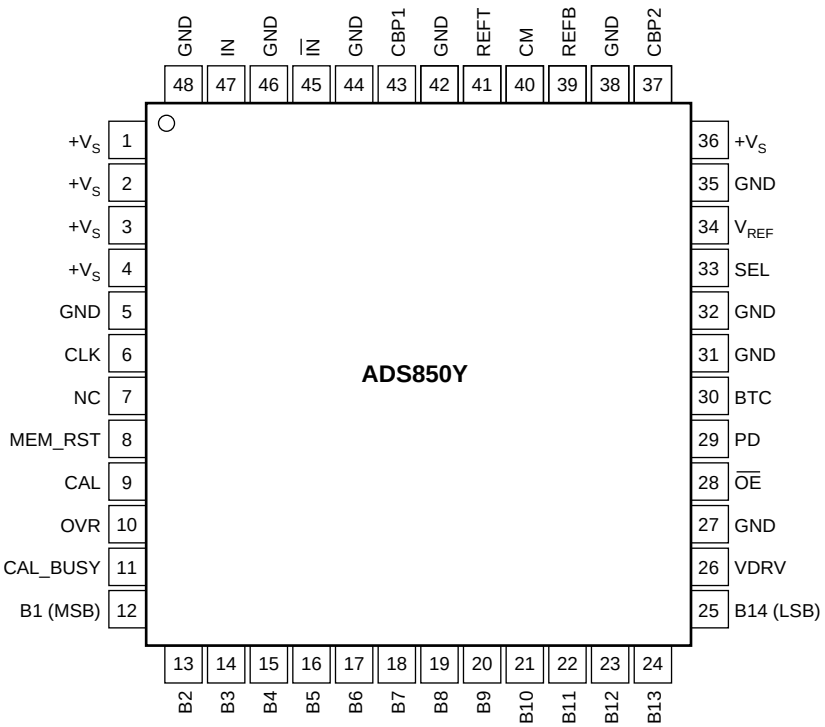
At $T_A$ = full specified temperature range, $V_S$ = +5V, specified differential input range = 1.5V to 3.5V, internal reference input, sampling rate = 10MSPS after calibration, and $V_{REF}$ = 2V, unless otherwise specified.

| PARAMETER | CONDITIONS | ADS850Y MIN | ADS850Y TYP | ADS850Y MAX | UNITS |
|---|---|---|---|---|---|
| **DIGITAL INPUTS** | | | | | |
| Logic Family | | | +3V/+5V Logic Compatible CMOS | | |
| Convert Command | Start Conversion | | Rising Edge of Convert Clock | | |
| High Level Input Current ($V_{IN}$ = 5V)[4] | | | | 100 | µA |
| Low Level Input Current ($V_{IN}$ = 0V) | | | | ±10 | µA |
| High Level Input Voltage | | +2.0 | | | V |
| Low Level Input Voltage | | | | +1.0 | V |
| Input Capacitance | | | 5 | | pF |
| **DIGITAL OUTPUTS** | | | | | |
| Logic Family | | | +3V/+5V Logic Compatible CMOS | | V |
| Logic Coding | | | Straight Offset Binary | | |
| Low Output Voltage | ($I_{OL}$ = 50µA) | | | 0.1 | V |
| Low Output Voltage | ($I_{OL}$ = 1.6mA) | | | 0.4 | V |
| High Output Voltage | ($I_{OH}$ = 50µA) | +4.5 | | | V |
| High Output Voltage | ($I_{OH}$ = 0.5mA) | +2.4 | | | V |
| 3-State Enable Time | $\overline{OE}$ = LOW | | 20 | 40 | ns |
| 3-State Disable Time | $\overline{OE}$ = HIGH | | 2 | 10 | ns |
| Output Capacitance | | | 5 | | pF |
| **ACCURACY (4Vp-p Input Range)** | | | | | |
| Zero Error (Referred to –FS) | At 25°C | | ±0.2 | | %FS |
| Zero Error Drift (Referred to –FS) | | | ±5 | | ppm/°C |
| Gain Error[5] | At 25°C | | ±0.7 | | %FS |
| Gain Error Drift[5] | | | ±15 | | ppm/°C |
| Gain Error[6] | At 25°C | | ±0.042 | | %FS |
| Gain Error Drift[6] | | | ±15 | | ppm/°C |
| Power-Supply Rejection of Gain | $\Delta V_S$ = ±5% | | 82 | | dB |
| Reference Input Resistance | | | 1.6 | | kΩ |
| Internal Voltage Reference Tolerance ($V_{REF}$ = 2.0V)[7] | At 25°C | | ±13.5mV | | mV |
| Internal Voltage Reference Tolerance ($V_{REF}$ = 1.0V)[7] | At 25°C | | ±6mV | | mV |
| **POWER-SUPPLY REQUIREMENTS** | | | | | |
| Supply Voltage: $+V_S$ | Operating | +4.7 | +5.0 | +5.3 | V |
| Supply Voltage: VDRV | Operating | +2.7 | | +5.3 | V |
| Supply Current: $+I_S$ | Operating | | 53 | | mA |
| Power Dissipation VDRV = 3V | External Reference | | 240 | | mW |
| VDRV = 5V | External Reference | | 245 | | mW |
| VDRV = 3V | Internal Reference | | 250 | 275 | mW |
| VDRV = 5V | Internal Reference | | 255 | | mW |
| | Power-Down | | 20 | | mW |
| Thermal Resistance, $\theta_{JA}$ | | | | | |
| TQFP-48 | | | 56.5 | | °C/W |

NOTES: (1) Spurious-Free Dynamic Range refers to the difference in magnitude between the fundamental and the next largest harmonic. (2) dBFS means dB relative to full scale. (3) Effective number of bits (ENOB) is defined by (SINAD – 1.76)/6.02. (4) Internal 50kΩ pull-down resistor. (5) Includes internal reference. (6) Excludes internal reference. (7) Typical reference tolerance based on ±1 sigma of distribution.

## PIN CONFIGURATION

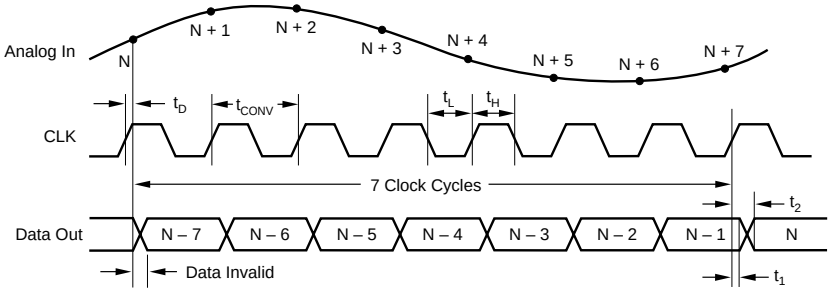
**Top View** **TQFP**




## PIN DESCRIPTIONS

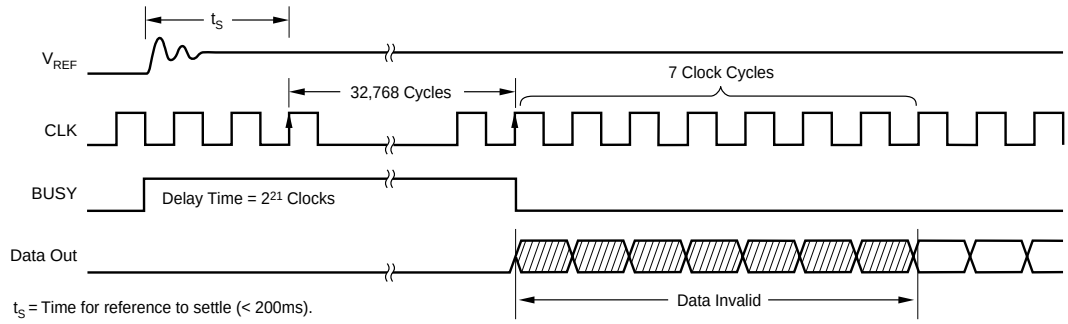
| PIN | I/O | DESIGNATOR | DESCRIPTION | PIN | I/O | DESIGNATOR | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| 1 | | $+V_S$ | +5V Supply | 27 | | GND | Ground |
| 2 | | $+V_S$ | +5V Supply | 28 | I | $\overline{OE}$ | Output Enable: HI = High Impedance; |
| 3 | | $+V_S$ | +5V Supply | | | | LO = Normal Operation (50kΩ Internal |
| 4 | | $+V_S$ | +5V Supply | | | | Pull-Down Resistor) |
| 5 | | GND | Ground | 29 | I | PD | Power Down: HI = Power Down; LO = Normal |
| 6 | I | CLK | Convert Clock Input | | | | Operation (50kΩ Internal Pull-Down Resistor) |
| 7 | | NC | No Connection | 30 | I | BTC | HI = Binary Two's Complement (BTC); |
| 8 | I | MEM_RST | Memory Reset. When pulsed HIGH, | | | | LO = Straight Offset Binary (SOB) |
| | | | resets memory to zero. Not intended as | 31 | | GND | Ground |
| | | | a function pin, so should be perma- | 32 | | GND | Ground |
| | | | nently tied to ground. | 33 | | SEL | Input Range Select |
| 9 | I | CAL | When Pulsed High, puts ADC into Cali- | 34 | I/O | $V_{REF}$ | Reference Voltage Select |
| | | | bration Mode (2 clock cycles). | 35 | | GND | Ground |
| 10 | | OVR | Over Range Indicator | 36 | | $+V_S$ | +5V Supply |
| 11 | | CAL_BUSY | Indicates in Calibration Mode. | 37 | | CBP2 | Calibration Reference Bypass 2 (0.1µF ce- |
| 12 | O | B1 (MSB) | Data Bit 1 (D13) (MSB) | | | | ramic capacitor recommended for decou- |
| 13 | O | B2 | Data Bit 2 (D12) | | | | pling.) |
| 14 | O | B3 | Data Bit 3 (D11) | 38 | | GND | Ground |
| 15 | O | B4 | Data Bit 4 (D10) | 39 | I/O | REFB | Bottom Reference Voltage Bypass |
| 16 | O | B5 | Data Bit 5 (D9) | 40 | O | CM | Common-Mode Voltage (mid-scale). Not in- |
| 17 | O | B6 | Data Bit 6 (D8) | | | | tended for driving a load. |
| 18 | O | B7 | Data Bit 7 (D7) | 41 | I/O | REFT | Top Reference Voltage Bypass |
| 19 | O | B8 | Data Bit 8 (D6) | 42 | | GND | Ground |
| 20 | O | B9 | Data Bit 9 (D5) | 43 | | CBP1 | Calibration Reference Bypass 1 (0.1µF ce- |
| 21 | O | B10 | Data Bit 10 (D4) | | | | ramic capacitor recommended for decou- |
| 22 | O | B11 | Data Bit 11 (D3) | | | | pling.) |
| 23 | O | B12 | Data Bit 12 (D2) | 44 | | GND | Ground |
| 24 | O | B13 | Data Bit 13 (D1) | 45 | I | $\overline{IN}$ | Complementary Analog Input (–) |
| 25 | O | B14 (LSB) | Data Bit 14 (D0) (LSB) | 46 | | GND | Ground |
| 26 | | VDRV | Output Driver Voltage | 47 | I | IN | Analog Input (+) |
| | | | | 48 | | GND | Ground |

# TIMING DIAGRAMS

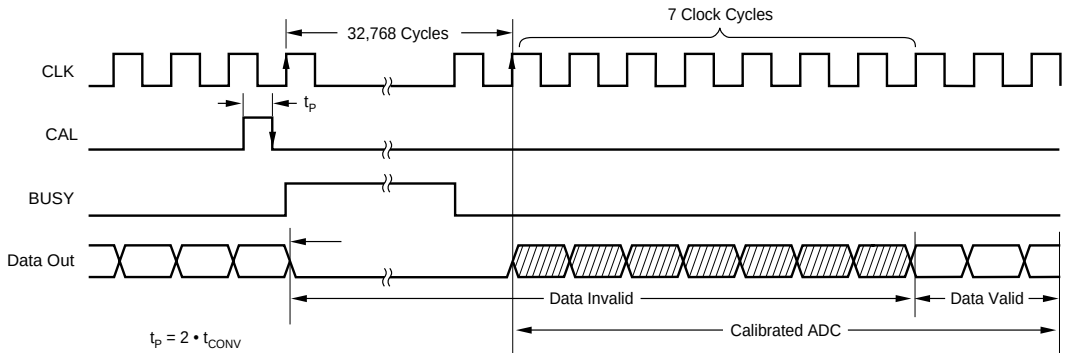



| SYMBOL | DESCRIPTION | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| $t_{CONV}$ | Convert Clock Period | 100 | | 100µs | ns |
| $t_L$ | Clock Pulse LOW | 48 | $t_{CONV}/2$ | | ns |
| $t_H$ | Clock Pulse HIGH | 48 | $t_{CONV}/2$ | | ns |
| $t_D$ | Aperture Delay | | 2 | | ns |
| $t_1$ | Data Hold Time, $C_L$ = 0pF | 3.9 | | | ns |
| $t_2$ | New Data Delay Time, $C_L$ = 15pF max | | | 12 | ns |

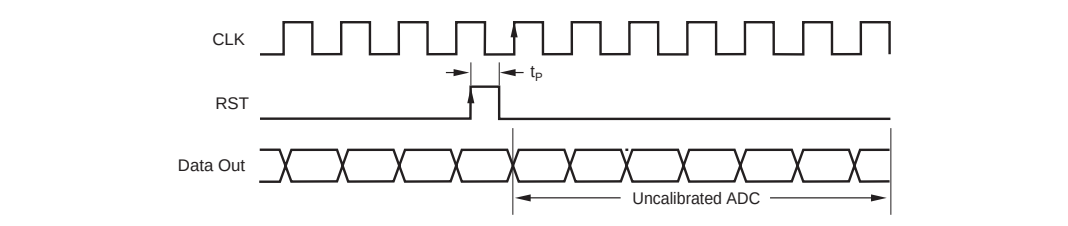
TIMING DIAGRAM 1. Pipeline Delay Timing.




TIMING DIAGRAM 2. Power-On Calibration Mode Timing.




TIMING DIAGRAM 3. Calibration-On-Demand Mode Timing.

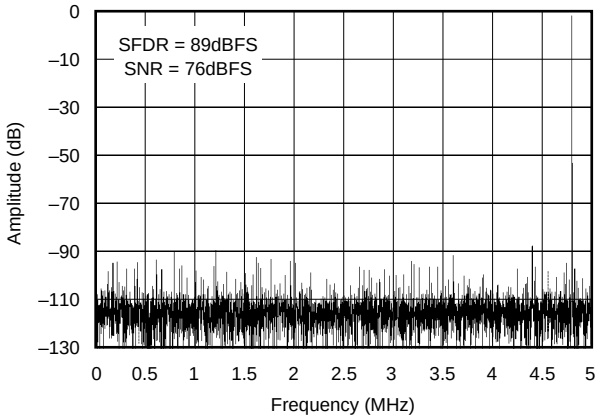



TIMING DIAGRAM 4. Reset Mode Timing.

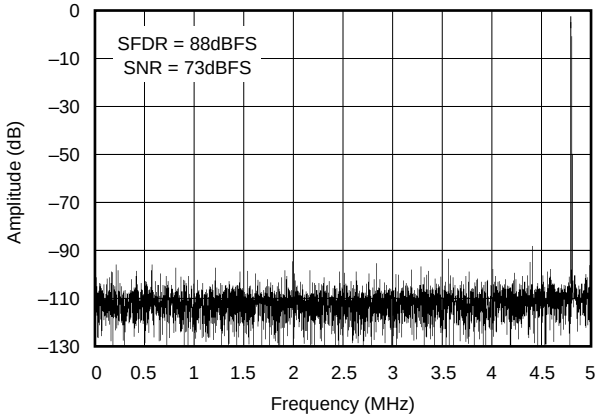
# TYPICAL CHARACTERISTICS

At $T_A$ = full specified temperature range, $V_S$ = +5V, specified input range = 1.5V to 3.5V, differential internal reference input and sampling rate = 10MSPS after calibration, $V_{REF}$ = 2V, –1dB input, unless otherwise specified.

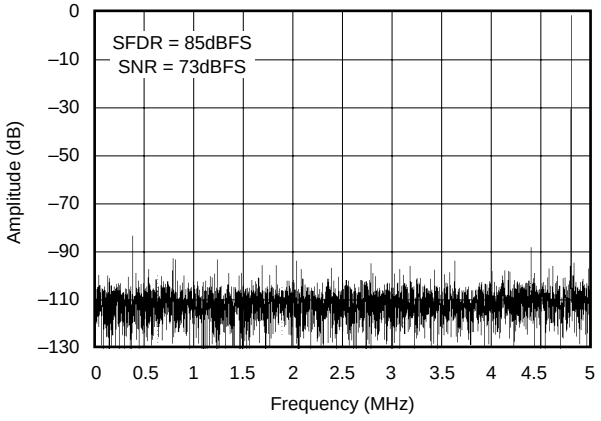
SPECTRAL PERFORMANCE
(4Vp-p, Differential, $f_{IN}$ = 4.8MHz)



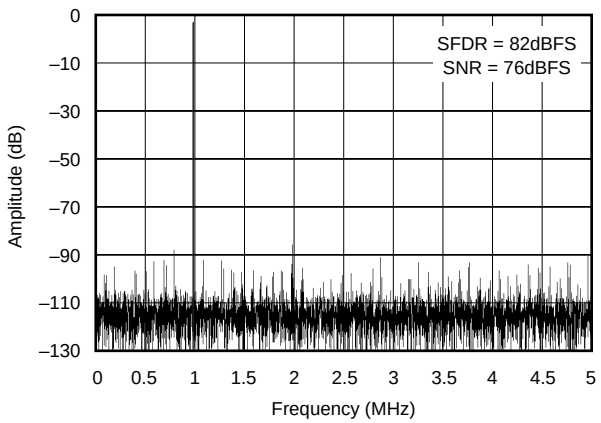

SPECTRAL PERFORMANCE
(2Vp-p, Differential, $f_{IN}$ = 4.8MHz)



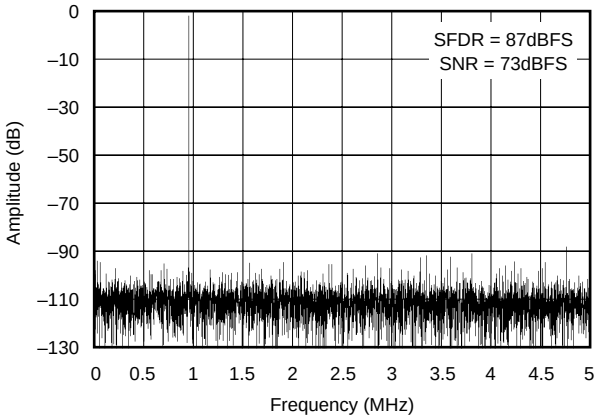

SPECTRAL PERFORMANCE
(2Vp-p, Single-Ended, $f_{IN}$ = 4.8MHz)



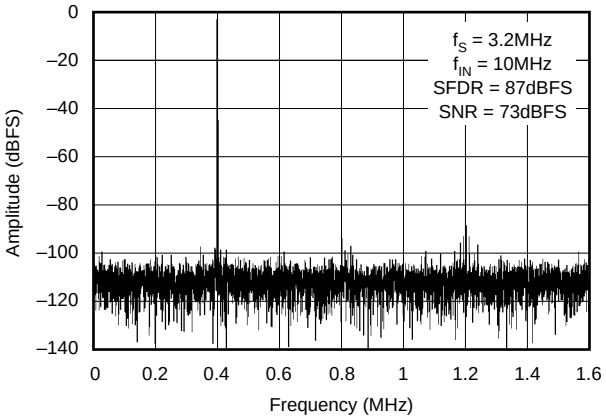

SPECTRAL PERFORMANCE
(4Vp-p, Differential, $f_{IN}$ = 1MHz)




SPECTRAL PERFORMANCE
(2Vp-p, Single-Ended, $f_{IN}$ = 1MHz)



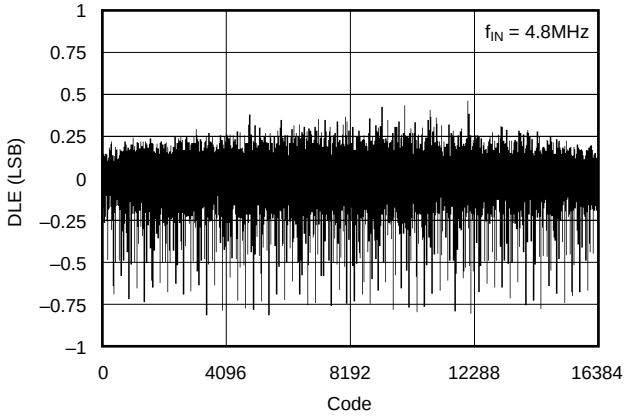

UNDERSAMPLING
(Differential, 4Vp-p)



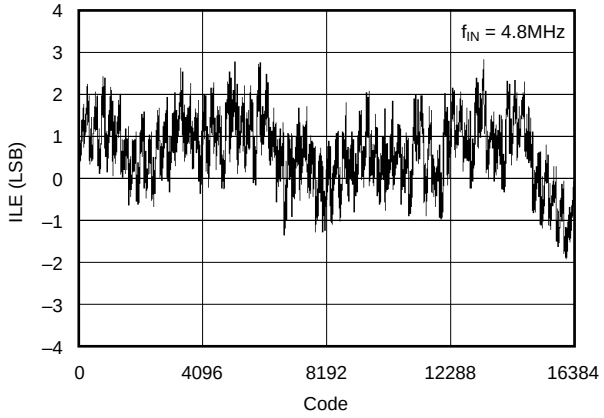
# TYPICAL CHARACTERISTICS (Cont.)

At $T_A$ = full specified temperature range, $V_S$ = +5V, specified input range = 1.5V to 3.5V, differential internal reference input and sampling rate = 10MSPS after calibration, $V_{REF}$ = 2V, –1dB input, unless otherwise specified.

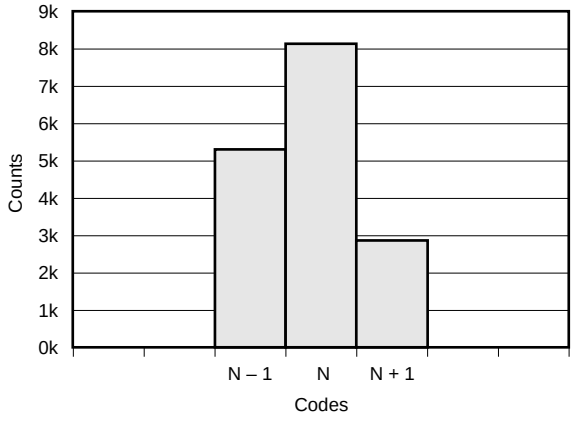
DIFFERENTIAL LINEARITY ERROR



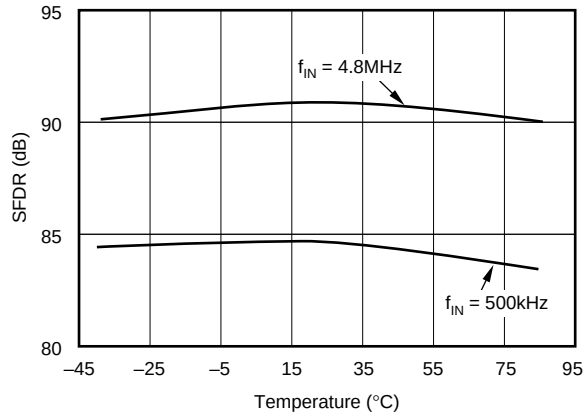

INTEGRAL LINEARITY ERROR



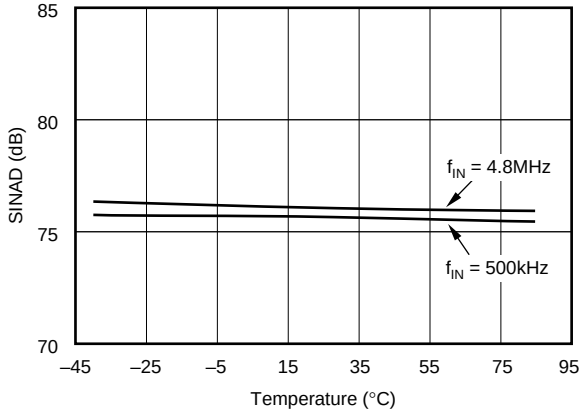

OUTPUT NOISE HISTOGRAM
(4Vp-p)



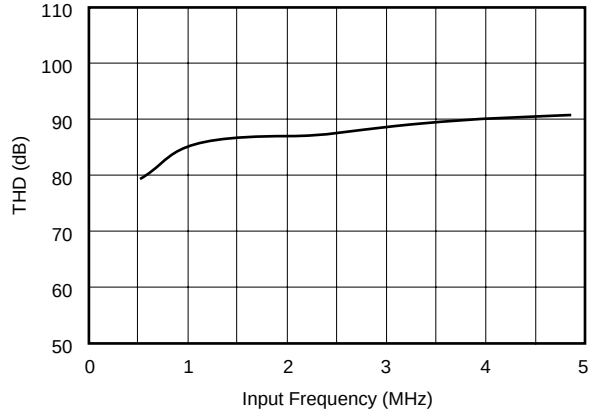

SFDR vs TEMPERATURE




SINAD vs TEMPERATURE



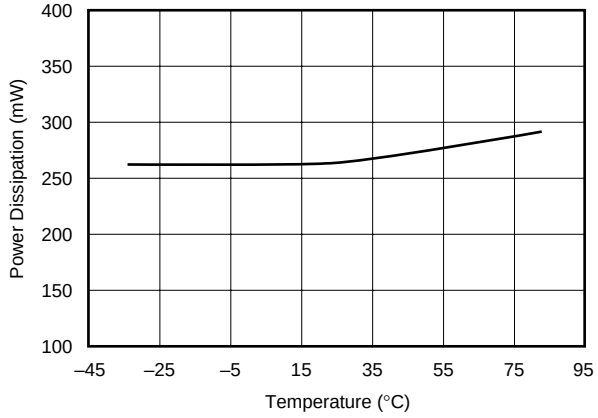

THD vs INPUT FREQUENCY



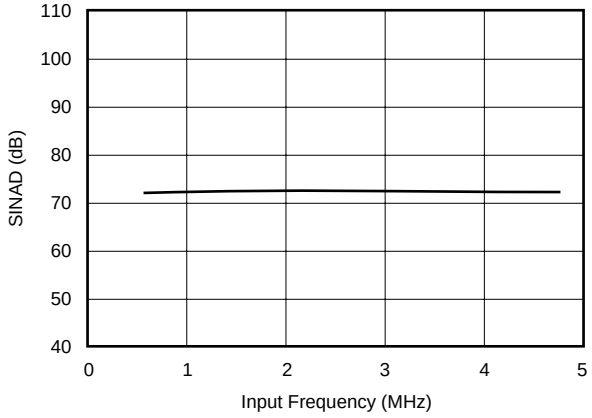
# TYPICAL CHARACTERISTICS (Cont.)

At $T_A$ = full specified temperature range, $V_S$ = +5V, specified input range = 1.5V to 3.5V, differential internal reference input and sampling rate = 10MSPS after calibration, $V_{REF}$ = 2V, –1dB input, unless otherwise specified.

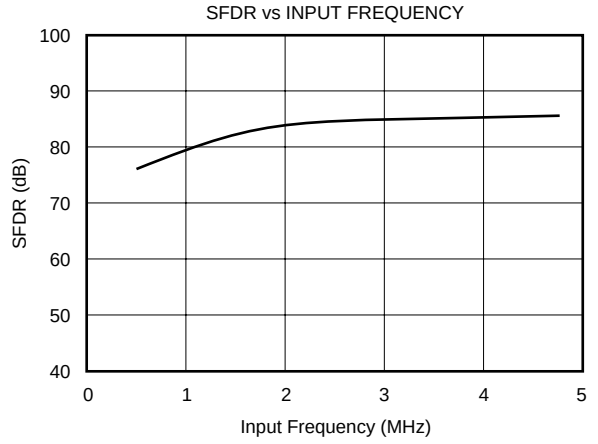
POWER DISSIPATION vs TEMPERATURE



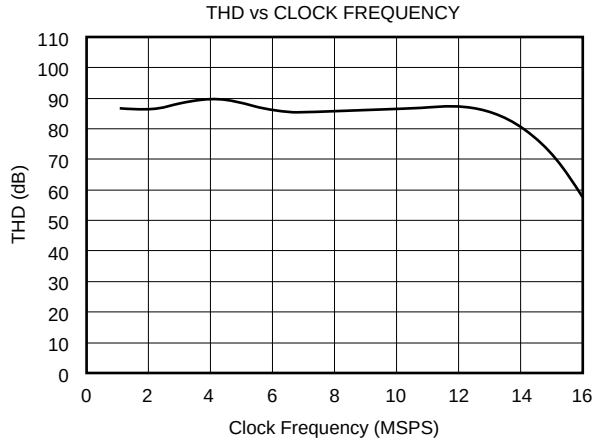

SINAD vs INPUT FREQUENCY



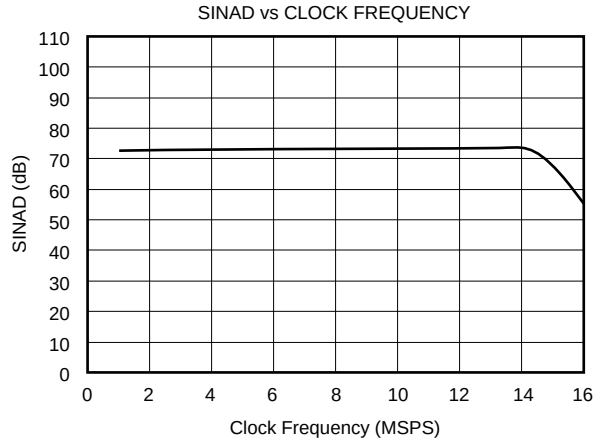

SFDR vs INPUT FREQUENCY



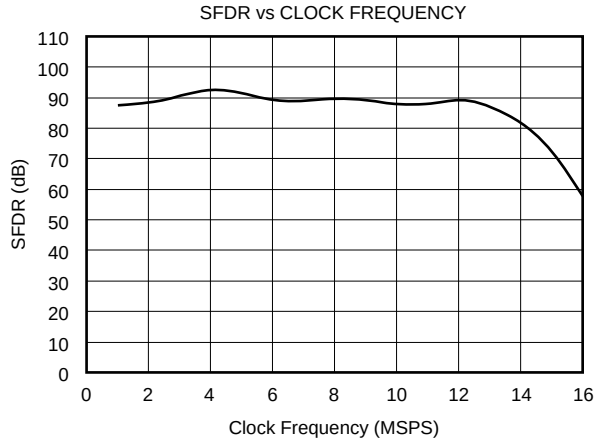

THD vs CLOCK FREQUENCY




SINAD vs CLOCK FREQUENCY

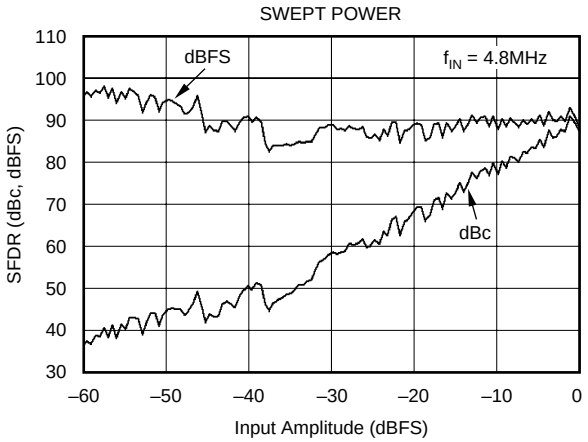



SFDR vs CLOCK FREQUENCY



# TYPICAL CHARACTERISTICS (Cont.)

At $T_A$ = full specified temperature range, $V_S$ = +5V, specified input range = 1.5V to 3.5V, differential internal reference input and sampling rate = 10MSPS after calibration, $V_{REF}$ = 2V, –1dB input, unless otherwise specified.




# APPLICATION INFORMATION

## DRIVING THE ANALOG INPUT

The ADS850 allows its analog inputs to be driven either single-ended or differentially. The focus of the following discussion is on the single-ended configuration.

## CALIBRATION PROCEDURE

The calibration procedure (CAL) is started by a positive pulse, with a minimum width of 2 clock cycles. Once calibration is initiated, the clock must operate continuously and the power supplies and references must remain stable. The calibration registers are reset on the rising edge of the CAL signal. The actual calibration procedure begins at the falling edge of the CAL signal. Calibration is completed at the end of 32,775 cycles at 10MSPS, CAL = 3.28ms (see Timing Diagram 3 on page 5). During calibration, the CAL_BUSY signal stays HIGH and the digital output pins of the ADC are forced to zero. Also, during calibration, the inputs (IN and $\overline{IN}$) are disabled. When the calibration procedure is complete, the CAL_BUSY goes LOW. Valid data appears at the output seven cycles later or after a total of 32,775 clock cycles. If there are any changes to the clock or the temperature changes more than ±20°C, the ADC should be re-calibrated to maintain performance.

At power-on (see Timing Diagram 2 on page 5), the ADC calibrates itself. The power-on delay, $t_S$, is the time it takes for the reference voltage to settle. Once the clock starts, the power-on delay operates for $2^{21}$ clock cycles. Bypass capacitors should be selected to allow the reference to settle within 200ms. If the system is noisy or external references require a longer settling time, a CAL pulse may be required.

## AC-COUPLED INPUT CONFIGURATION

See Figure 1 for the circuit example of the most common interface configuration for the ADS850. With the $V_{REF}$ pin connected to the SEL pin, the full-scale input range is defined to be 2Vp-p. This signal is ac-coupled in single-ended form to the ADS850 using the low distortion voltage-feedback amplifier OPA642. As is generally necessary for single-supply components, operating the ADS850 with a full-scale input signal swing requires a level-shift of the amplifier's zero-centered analog signal to comply with the ADC's input range requirements. Using a DC blocking capacitor between the output of the driving amplifier and the converter's input, a simple level-shifting scheme can be implemented. In this configuration, the top and bottom references (REFT, REFB) provide an output voltage of +3V and +2V, respectively. Here, two resistor pairs of 2 • 2kΩ are used to create a common-mode voltage of approximately +2.5V to bias the inputs of the ADS850 (IN, $\overline{IN}$) to the required DC voltage.

An advantage of ac-coupling is that the driving amplifier still operates with a ground-based signal swing. This will keep the distortion performance at its optimum since the signal swing stays centered within the linear region of the op amp and sufficient headroom to the supply rails can be maintained. Consider using the inverting gain configuration to eliminate CMR induced errors of the amplifier. The addition of a small series resistor ($R_S$) between the output of the op amp and the input of the ADS850 will be beneficial in almost all interface configurations. This will decouple the op amp's output from the capacitive load and avoid gain peaking, which can result in increased noise. For best spurious and distortion performance, the resistor value should be kept below 100Ω. Furthermore, the series resistor together with the 100pF capacitor establish a passive low-pass filter, limiting the bandwidth for the wideband noise, thus help improving the SNR performance.

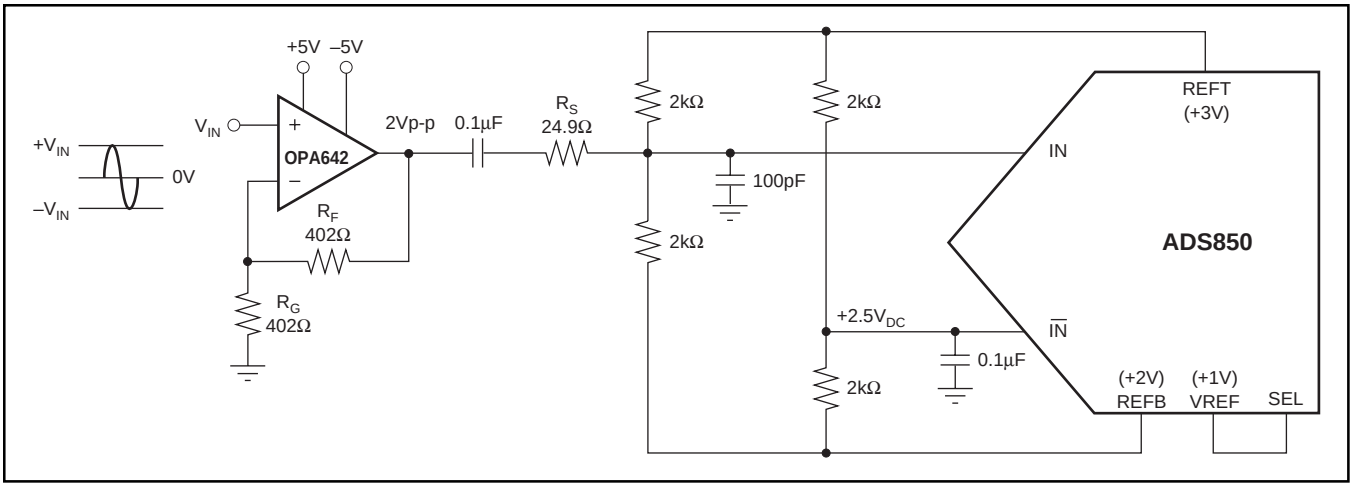



FIGURE 1. AC-Coupled Input Configuration for 2Vp-p Input Swing and Common-Mode Voltage at +2.5V Derived from Internal Top and Bottom Reference.

## DC-COUPLED WITHOUT LEVEL SHIFT

In some applications the analog input signal may already be biased at a level which complies with the selected input range and reference level of the ADS850. In this case, it is only necessary to provide an adequately low source impedance to the selected input, IN or $\overline{IN}$. Always consider wideband op amps since their output impedance will stay low over a wide range of frequencies. For those applications requiring the driving amplifier to provide a signal amplification, with a gain ≥ 3, consider using the decompensated voltage feedback op amp OPA686.

## DC-COUPLED WITH LEVEL SHIFT

Several applications may require that the bandwidth of the signal path include DC, in which case the signal has to be DC-coupled to the ADC. In order to accomplish this, the interface circuit has to provide a DC-level shift. The circuit shown in Figure 2 employs an op amp, OPA681, to sum the ground centered input signal with a required DC offset. The ADS850 typically operates with a +2.5V common-mode voltage, which is established at the center tap of the ladder and connected to the $\overline{IN}$ input of the converter. The OPA681 operates in inverting configuration. Here resistors $R_1$ and $R_2$ set the DC-bias level for the OPA691. Because of the op amp's noise gain of +2V/V, assuming $R_F = R_{IN}$, the DC offset voltage applied to its noninverting input has to be divided down to +1.25V, resulting in a DC output voltage of +2.5V. DC voltage differences between the IN and $\overline{IN}$ inputs of the ADS850 effectively will produce an offset, which can be corrected for by adjusting the values of resistors $R_1$ and $R_2$. The bias current of the op amp may also result in an undesired offset. The selection criteria of the appropriate op amp should include the input bias current, output voltage swing, distortion and noise specification. Note that in this example the overall signal phase is inverted. To re-establish the original signal polarity, it is always possible to interchange the IN and $\overline{IN}$ connections.

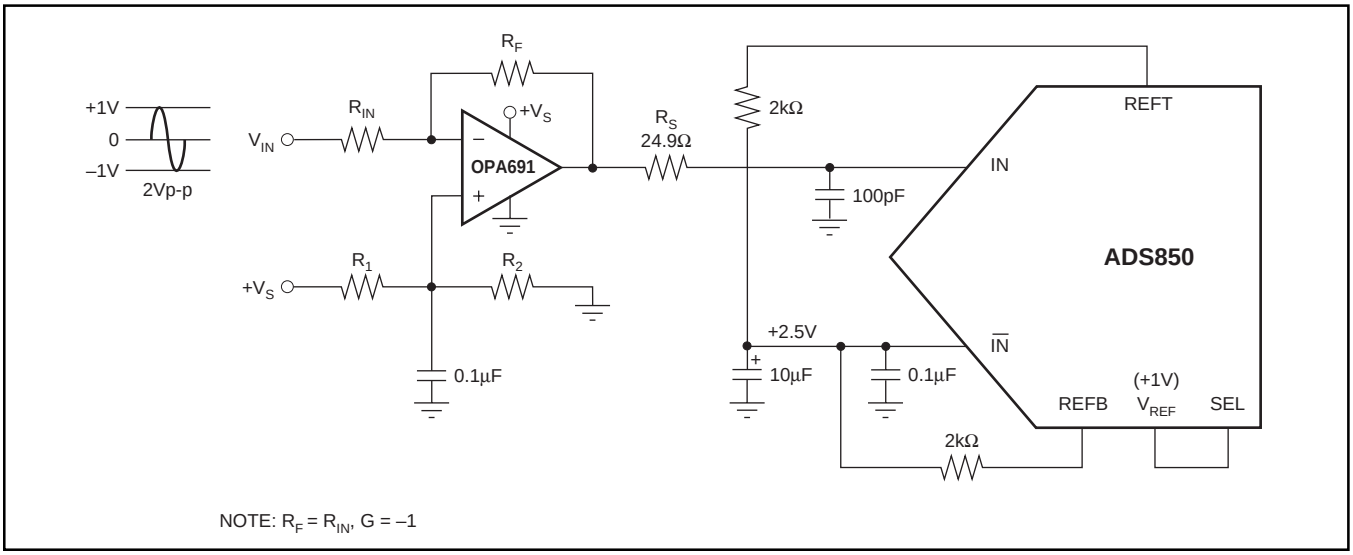



FIGURE 2. DC-Coupled, Single-Ended Input Configuration with DC-level Shift.

## SINGLE-ENDED-TO-DIFFERENTIAL CONFIGURATION (TRANSFORMER COUPLED)

In order to select the best suited interface circuit for the ADS850, the performance requirements must be known. If an ac-coupled input is needed for a particular application, the next step is to determine the method of applying the signal; either single-ended or differentially. The differential input configuration may provide a noticeable advantage of achieving good SFDR performance based on the fact that in the differential mode, the signal swing can be reduced to half of the swing required for single-ended drive. Secondly, by driving the ADS850 differentially, the even-order harmonics will be reduced. Figure 3 shows the schematic for the suggested transformer-coupled interface circuit. The resistor across the secondary side ($R_T$) should be set to get an input impedance match (e.g., $R_T = n^2 \bullet R_G$).

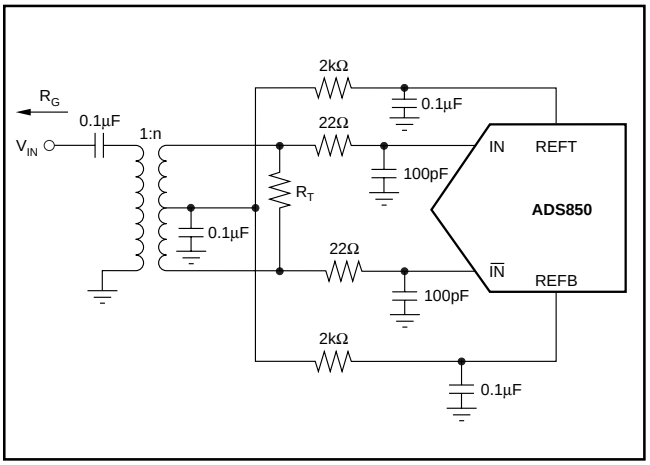



FIGURE 3. Transformer-Coupled Input.

## REFERENCE OPERATION

Integrated into the ADS850 is a bandgap reference circuit including logic that provides either a +1V or +2V reference output, by simply selecting the corresponding pin-strap configuration. For more design flexibility, the internal reference can be shut off and an external reference voltage used. Table I provides an overview of the possible reference options and pin configurations.

| MODE | INPUT RANGE | SEL | $V_{REF}$ | REFB | REFT |
|---|---|---|---|---|---|
| Internal | 2Vp-p | $V_{REF}$ | SEL | NC | NC |
| Internal | 4Vp-p | GND | NC | NC | NC |
| External | 2V < FSR < 4V | $+V_S$ | 1V < FSR < 2V | NC | NC |
| External | (REFB – REFT) • 2 | $+V_S$ | GND | 1.5V < REFB < 2V | 2V < REFT <3.5V |

TABLE I. Selected Reference Configuration Examples.

A simple model of the internal reference circuit is shown in Figure 4. The internal blocks are a 1V bandgap voltage reference, buffer, the resistive reference ladder, and the drivers for the top and bottom reference which supply the necessary current to the internal nodes. As shown, the output of the buffer appears at the $V_{REF}$ pin. The full-scale input span of the ADS850 is determined by the voltage at $V_{REF}$, according to Equation 1:

$$\text{Full-Scale Input Span} = 2 \bullet V_{REF} \quad (1)$$

Note that the current drive capability of this amplifier is limited to about 1mA and should not be used to drive low loads. The programmable reference circuit is controlled by the voltage applied to the select pin (SEL). Refer to Table I for an overview.

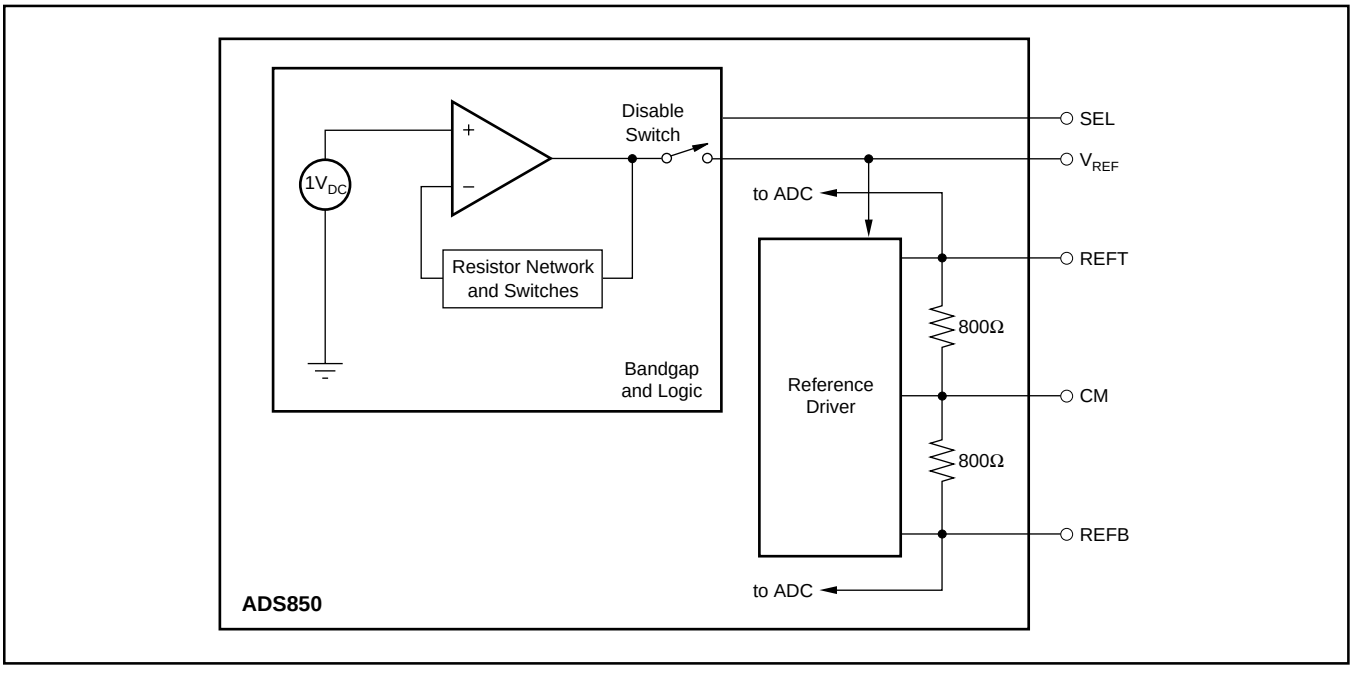



FIGURE 4. Equivalent Reference Circuit.

The top reference (REFT) and the bottom reference (REFB) are brought out mainly for external bypassing. For proper operation with all reference configurations, it is necessary to provide solid bypassing to the reference pins in order to keep the clock feedthrough to a minimum. Figure 5 shows the recommended reference decoupling configuration.

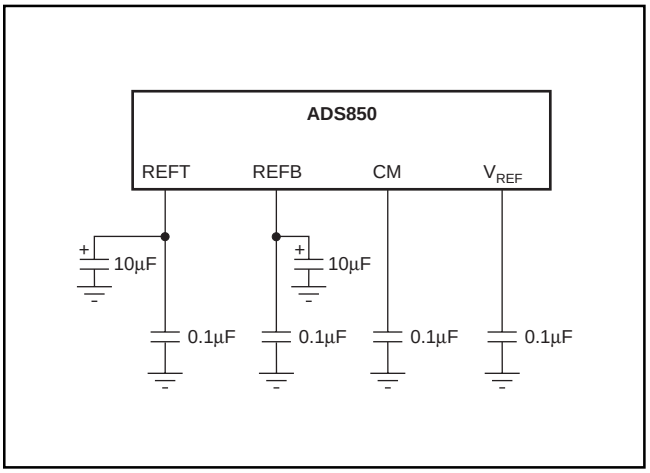



FIGURE 5. Recommended Reference Bypassing Scheme.

In addition, the Common-Mode Voltage (CMV) may be used as a reference level to provide the appropriate offset for the driving circuitry. However, care must be taken not to appreciably load this node, which is not buffered and has a high impedance. An alternate method of generating a common-mode voltage is given in Figure 6. Here, two external precision resistors (tolerance 1% or better) are located between the top and bottom reference pins. The common-mode level will appear at the midpoint. The output buffers of the top and bottom reference are designed to supply approximately 2mA of output current.

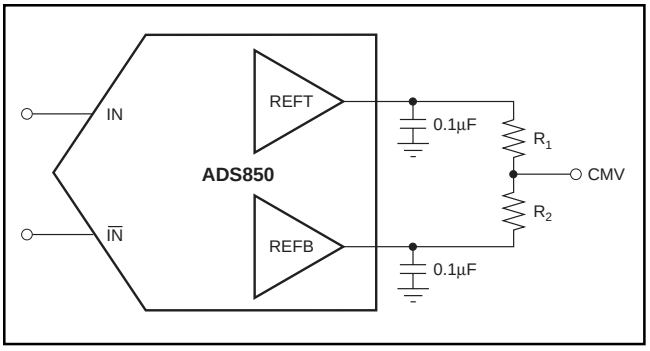



FIGURE 6. Alternative Circuit to Generate Common-Mode Voltage.

## EXTERNAL REFERENCE OPERATION

Depending on the application requirements, it might be advantageous to operate the ADS850 with an external reference. This may improve the DC accuracy if the external reference circuitry is superior in its drift and accuracy. To use the ADS850 with an external reference, the user must disable the internal reference, as shown in Figure 7. By connecting the SEL pin to $+V_S$, the internal logic will shut down the internal reference. At the same time, the output of the internal reference buffer is disconnected from the $V_{REF}$ pin, which now must be driven with the external reference. Note that a similar bypassing scheme should be maintained as described for the internal reference operation.

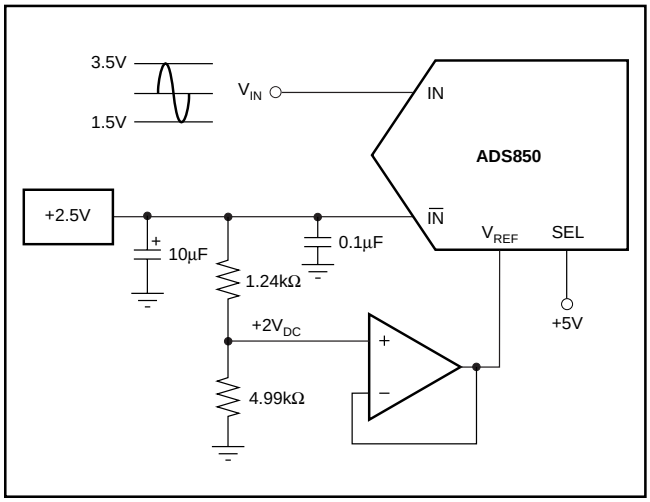



FIGURE 7. External Reference, Input Range 1.5V to 3.5V (2Vp-p), Single-Ended, with +2.5V Common-Mode Voltage.

## DIGITAL INPUTS AND OUTPUTS

### Over Range (OVR)

One feature of the ADS850 is its 'Over Range' digital output (OVR). This pin can be used to monitor any out-of-range condition, which occurs every time the applied analog input voltage exceeds the input range (set by $V_{REF}$). The OVR output is LOW when the input voltage is within the defined input range. It becomes HIGH when the input voltage is beyond the input range. This is the case when the input voltage is either below the bottom reference voltage or above the top reference voltage. OVR will remain active until the analog input returns to its normal signal range and another conversion is completed. Using the MSB and its complement in conjunction with OVR a simple clue logic can be built that detects the overrange and underrange conditions, as shown in Figure 8. It should be noted that OVR is a digital output which is updated along with the bit information corresponding to the particular sampling incidence of the analog signal. Therefore, the OVR data is subject to the same pipeline delay (latency) as the digital data.

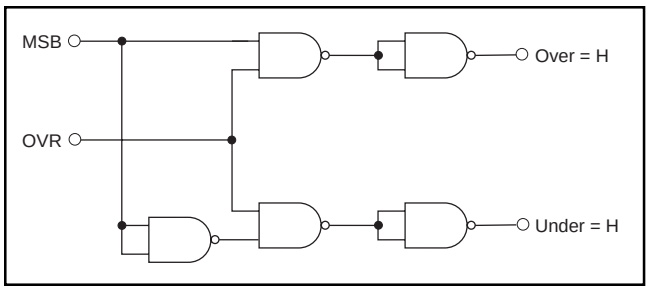



FIGURE 8. External Logic for Decoding Under- and Over-Range Condition.

## CLOCK INPUT REQUIREMENTS

Clock jitter is critical to the SNR performance of high-speed, high-resolution ADCs. It leads to aperture jitter ($t_A$) which adds noise to the signal being converted. The ADS850 samples the input signal on the rising edge of the CLK input. Therefore, this edge should have the lowest possible jitter. The jitter noise contribution to total SNR is given by the following equation. If this value is near your system requirements, input clock jitter must be reduced.

$$\text{Jitter SNR} = 20\log\frac{1}{2\pi f_{IN} t_A}\ \text{rms signal to rms noise}$$

Where: $f_{IN}$ is Input Signal Frequency

$t_A$ is rms Clock Jitter

Particularly in undersampling applications, special consideration should be given to clock jitter. The clock input should be treated as an analog input in order to achieve the highest level of performance. Any overshoot or undershoot of the clock signal may cause degradation of the performance. When digitizing at high sampling rates, the clock should have a 50% duty cycle ($t_H = t_L$), along with fast rise and fall times of 2ns or less.

## DIGITAL OUTPUTS

The digital outputs of the ADS850 are designed to be compatible with both high speed TTL and CMOS logic families. The driver stage for the digital outputs is supplied through a separate supply pin, VDRV, which is not connected to the analog supply pins. By adjusting the voltage on VDRV, the digital output levels will vary respectively. Therefore, it is possible to operate the ADS850 on a +5V analog supply while interfacing the digital outputs to 3V logic.

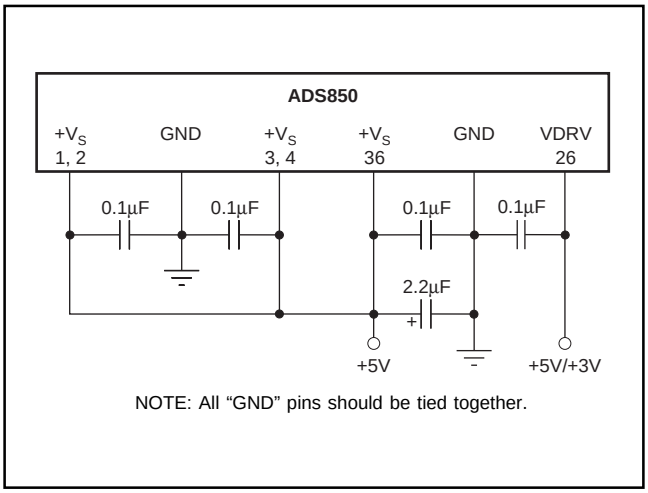
It is recommended to keep the capacitive loading on the data lines as low as possible (≤ 15pF). Larger capacitive loads demand higher charging currents as the outputs are changing. Those high current surges can feed back to the analog portion of the ADS850 and influence the performance. If necessary, external buffers or latches may be used which provide the added benefit of isolating the ADS850 from any digital noise activities on the bus coupling back high frequency noise. In addition, resistors in series with each data line may help maintain the ac performance of the ADS850. Their use depends on the capacitive loading seen by the converter. Values in the range of 100Ω to 200Ω will limit the instantaneous current the output stage has to provide for recharging the parasitic capacitances, as the output levels change from LOW to HIGH or HIGH to LOW.

## GROUNDING AND DECOUPLING

Proper grounding and bypassing, short lead length, and the use of ground planes are particularly important for high frequency designs. Multi-layer PC boards are recommended for best performance since they offer distinct advantages like minimizing ground impedance, separation of signal layers by ground layers, etc. It is recommended that the analog and digital ground pins of the ADS850 be joined together at the IC and be connected only to the analog ground of the system.

The ADS850 has analog and digital supply pins, however, the converter should be treated as an analog component and all supply pins should be powered by the analog supply. This will ensure the most consistent results, since digital supply lines often carry high levels of noise that would otherwise be coupled into the converter and degrade the achievable performance.

Because of the pipeline architecture, the converter also generates high frequency current transients and noise that are fed back into the supply and reference lines. This requires that the supply and reference pins be sufficiently bypassed. Figure 9 shows the recommended decoupling scheme for the analog supplies. In most cases, 0.1µF ceramic chip capacitors are adequate to keep the impedance low over a wide frequency range. Their effectiveness largely depends on the proximity to the individual supply pin. Therefore, they should be located as close to the supply pins as possible. In addition, a larger size bipolar capacitor (1µF to 22µF) should be placed on the PC board in close proximity to the converter circuit.




NOTE: All "GND" pins should be tied together.

FIGURE 9. Recommended Bypassing for Analog Supply Pins.

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ADS850Y/250 | ACTIVE | TQFP | PFB | 48 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | | ADS850Y | Samples |
| ADS850Y/250G4 | ACTIVE | TQFP | PFB | 48 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | | ADS850Y | Samples |
| ADS850Y/2K | ACTIVE | TQFP | PFB | 48 | 2000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR | | ADS850Y | 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.
**OBSOLETE:** TI has discontinued the production of the device.

**(2)** Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
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**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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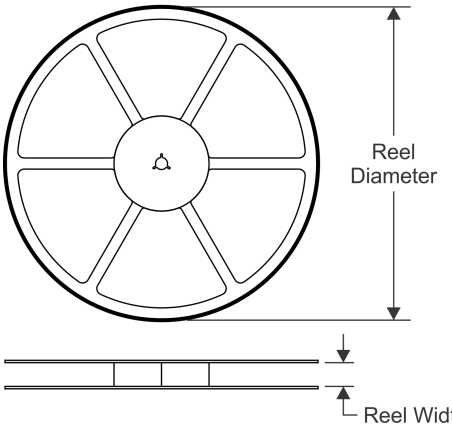
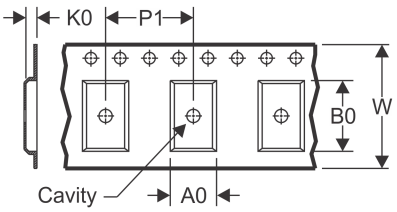
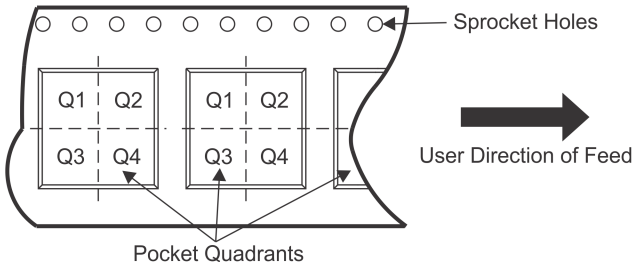



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

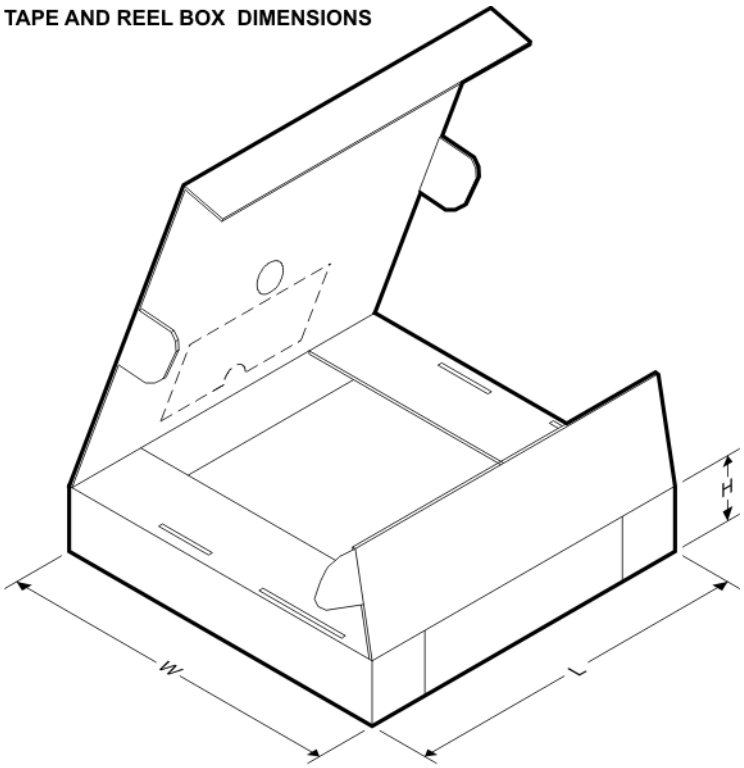
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ADS850Y/250 | TQFP | PFB | 48 | 250 | 177.8 | 16.4 | 9.6 | 9.6 | 1.5 | 12.0 | 16.0 | Q2 |

**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| ADS850Y/250 | TQFP | PFB | 48 | 250 | 210.0 | 185.0 | 35.0 |

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No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

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