

## ADC78H90 8-Channel, 500 kSPS, 12-Bit A/D Converter

Check for Samples: [ADC78H90](#)

### FEATURES

- Eight input channels
- Variable power management
- Independent analog and digital supplies
- SPI™/QSPI™/MICROWIRE™/DSP compatible
- Packaged in 16-lead TSSOP

### APPLICATIONS

- Automotive Navigation
- Portable Systems
- Medical Instruments
- Mobile Communications
- Instrumentation and Control Systems

### KEY SPECIFICATIONS

- Conversion Rate: 500kSPS
- DNL:  $\pm 1$ LSB (max)
- INL:  $\pm 1$ LSB (max)
- Power Consumption
  - 3V Supply: 1.5 mW (typ)
  - 5V Supply: 8.3 mW (typ)

### DESCRIPTION

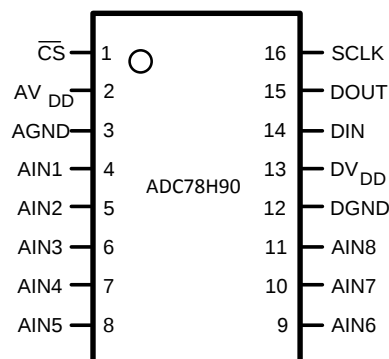
The ADC78H90 is a low-power, eight-channel CMOS 12-bit analog-to-digital converter with a conversion throughput of 500 kSPS. The converter is based on a successive-approximation register architecture with an internal track-and-hold circuit. It can be configured to accept up to eight input signals at inputs AIN1 through AIN8.

The output serial data is straight binary, and is compatible with several standards, such as SPI™, QSPI™, MICROWIRE™, and many common DSP serial interfaces.

The ADC78H90 may be operated with independent analog and digital supplies. The analog supply ( $AV_{DD}$ ) can range from +2.7V to +5.25V, and the digital supply ( $DV_{DD}$ ) can range from +2.7V to  $AV_{DD}$ . Normal power consumption using a +3V or +5V supply is 1.5 mW and 8.3 mW, respectively. The power-down feature reduces the power consumption to just 0.3  $\mu$ W using a +3V supply, or 0.5  $\mu$ W using a +5V supply.

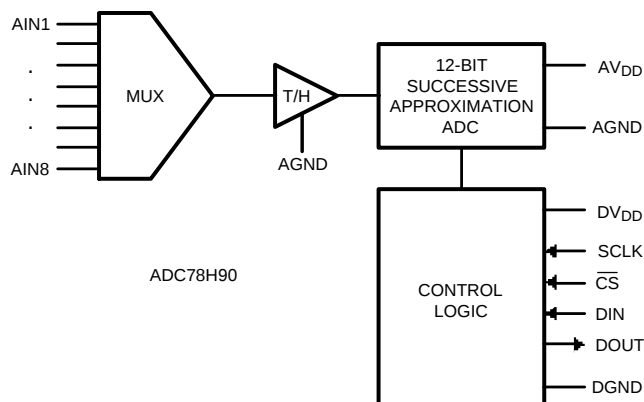
The ADC78H90 is packaged in a 16-lead TSSOP package. Operation over the industrial temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  is ensured.

### Connection Diagram



**Figure 1. 16-Lead TSSOP**  
See PW Package

### Block Diagram



### PIN DESCRIPTIONS AND EQUIVALENT CIRCUITS

| Pin No.            | Symbol       | Equivalent Circuit | Description                                                   |
|--------------------|--------------|--------------------|---------------------------------------------------------------|
| <b>ANALOG I/O</b>  |              |                    |                                                               |
| 4 - 11             | AIN1 to AIN8 |                    | Analog inputs. These signals can range from 0V to $AV_{DD}$ . |
| <b>DIGITAL I/O</b> |              |                    |                                                               |



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**PIN DESCRIPTIONS AND EQUIVALENT  
CIRCUITS (continued)**

| Pin No. | Symbol                 | Equivalent Circuit | Description                                                                                                                                                                            |
|---------|------------------------|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16      | SCLK                   |                    | Digital clock input. The range of frequencies for this input is 50 kHz to 8 MHz, with ensured performance at 8 MHz. This clock directly controls the conversion and readout processes. |
| 15      | DOUT                   |                    | Digital data output. The output samples are clocked out of this pin on falling edges of the SCLK pin.                                                                                  |
| 14      | DIN                    |                    | Digital data input. The ADC78H90's Control Register is loaded through this pin on rising edges of the SCLK pin.                                                                        |
| 1       | $\overline{\text{CS}}$ |                    | Chip select. On the falling edge of $\overline{\text{CS}}$ , a conversion process begins. Conversions continue as long as $\overline{\text{CS}}$ is held low.                          |

**POWER SUPPLY**
**PIN DESCRIPTIONS AND EQUIVALENT  
CIRCUITS (continued)**

| Pin No. | Symbol                  | Equivalent Circuit | Description                                                                                                                                                                                                                                         |
|---------|-------------------------|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2       | $\text{AV}_{\text{DD}}$ |                    | Positive analog supply pin. This pin should be connected to a quiet +2.7V to +5.25V source and bypassed to GND with a 1 $\mu\text{F}$ tantalum capacitor and a 0.1 $\mu\text{F}$ ceramic monolithic capacitor located within 1 cm of the power pin. |
| 13      | $\text{DV}_{\text{DD}}$ |                    | Positive digital supply pin. This pin should be connected to a +2.7V to $\text{AV}_{\text{DD}}$ supply, and bypassed to GND with a 0.1 $\mu\text{F}$ ceramic monolithic capacitor located within 1 cm of the power pin.                             |
| 3       | AGND                    |                    | The ground return for the analog supply and signals.                                                                                                                                                                                                |
| 12      | DGND                    |                    | The ground return for the digital supply and signals.                                                                                                                                                                                               |



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

**Absolute Maximum Ratings <sup>(1)(2)</sup>**

|                                                                        |                                                   |
|------------------------------------------------------------------------|---------------------------------------------------|
| Analog Supply Voltage $\text{AV}_{\text{DD}}$                          | –0.3V to 6.5V                                     |
| Digital Supply Voltage $\text{DV}_{\text{DD}}$                         | –0.3V to $\text{AV}_{\text{DD}}$ + 0.3V, max 6.5V |
| Voltage on Any Pin to GND                                              | –0.3V to $\text{AV}_{\text{DD}}$ + 0.3V           |
| Input Current at Any Pin <sup>(3)</sup>                                | ±10 mA                                            |
| Package Input Current <sup>(3)</sup>                                   | ±20 mA                                            |
| Power Dissipation at $T_A = 25^\circ\text{C}$                          | See <sup>(4)</sup>                                |
| ESD Susceptibility <sup>(5)</sup><br>Human Body Model<br>Machine Model | 2500V<br>250V                                     |
| Soldering Temperature, Infrared,<br>10 seconds <sup>(6)</sup>          | 260°C                                             |
| Junction Temperature                                                   | +150°C                                            |
| Storage Temperature                                                    | –65°C to +150°C                                   |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
- (3) When the input voltage at any pin exceeds the power supplies (that is,  $V_{\text{IN}} < \text{AGND}$  or  $V_{\text{IN}} > V_A$  or  $V_D$ ), the current at that pin should be limited to 10 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 10 mA to two.
- (4) The absolute maximum junction temperature ( $T_{\text{Jmax}}$ ) for this device is 150°C. The maximum allowable power dissipation is dictated by  $T_{\text{Jmax}}$ , the junction-to-ambient thermal resistance ( $\theta_{\text{JA}}$ ), and the ambient temperature ( $T_A$ ), and can be calculated using the formula  $P_{\text{DMAX}} = (T_{\text{Jmax}} - T_A) / \theta_{\text{JA}}$ . In the 16-pin TSSOP,  $\theta_{\text{JA}}$  is 96°C/W, so  $P_{\text{DMAX}} = 1,200\text{mW}$  at 25°C and 625 mW at the maximum operating ambient temperature of 85°C. Note that the power consumption of this device under normal operation is a maximum of 12 mW. The values for maximum power dissipation listed above will be reached only when the ADC78H90 is operated in a severe fault condition (e.g. when input or output pins are driven beyond the power supply voltages, or the power supply polarity is reversed). Obviously, such conditions should always be avoided.
- (5) Human body model is 100 pF capacitor discharged through a 1.5 k $\Omega$  resistor. Machine model is 220 pF discharged through ZERO ohms
- (6) See AN450, "Surface Mounting Methods and Their Effect on Product Reliability", or the section entitled "Surface Mount" found in any post 1986 Texas Instruments Linear Data Book, for other methods of soldering surface mount devices.

## Operating Ratings <sup>(1)(2)</sup>

|                                  |                                                         |
|----------------------------------|---------------------------------------------------------|
| Operating Temperature Range      | $-40^{\circ}\text{C} \leq T_A \leq +85^{\circ}\text{C}$ |
| AV <sub>DD</sub> Supply Voltage  | +2.7V to +5.25V                                         |
| DV <sub>DD</sub> Supply Voltage  | +2.7V to AV <sub>DD</sub>                               |
| Digital Input Pins Voltage Range | -0.3V to AV <sub>DD</sub>                               |
| Clock Frequency                  | 50 kHz to 8 MHz                                         |
| Analog Input Voltage             | 0V to AV <sub>DD</sub>                                  |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
- (2) All voltages are measured with respect to GND = 0V, unless otherwise specified.

## Package Thermal Resistance

| Package                             | $\theta_{JA}$ |
|-------------------------------------|---------------|
| 16-lead TSSOP on 4-layer, 2 oz. PCB | 96°C / W      |

## ADC78H90 Converter Electrical Characteristics <sup>(1)</sup>

The following specifications apply for  $AV_{DD} = DV_{DD} = +2.7V$  to  $5.25V$ ,  $AGND = DGND = 0V$ ,  $f_{SCLK} = 8\text{ MHz}$ ,  $f_{SAMPLE} = 500\text{ KSPS}$ , unless otherwise noted. **Boldface limits apply for  $T_A = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = 25^\circ\text{C}$ .

| Symbol                              | Parameter                                      | Conditions                                                                                                      | Typical                   | Limits<br>(2)         | Units      |
|-------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------|-----------------------|------------|
| STATIC CONVERTER CHARACTERISTICS    |                                                |                                                                                                                 |                           |                       |            |
|                                     | Resolution with No Missing Codes               |                                                                                                                 |                           | 12                    | Bits       |
| INL                                 | Integral Non-Linearity                         | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±1                    | LSB (max)  |
| DNL                                 | Differential Non-Linearity                     | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±1                    | LSB (max)  |
| V <sub>OFF</sub>                    | Offset Error                                   | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±2                    | LSB (max)  |
| OEM                                 | Offset Error Match                             | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±2                    | LSB (max)  |
| GE                                  | Gain Error                                     | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±3                    | LSB (max)  |
| GEM                                 | Gain Error Match                               | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V                                                              |                           | ±3                    | LSB (max)  |
| DYNAMIC CONVERTER CHARACTERISTICS   |                                                |                                                                                                                 |                           |                       |            |
| SINAD                               | Signal-to-Noise Plus Distortion Ratio          | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>IN</sub> = 40.2 kHz, −0.02 dBFS                   | 73                        | 70                    | dB (min)   |
| SNR                                 | Signal-to-Noise Ratio                          | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>IN</sub> = 40.2 kHz, −0.02 dBFS                   | 73                        | 70.8                  | dB (min)   |
| THD                                 | Total Harmonic Distortion                      | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>IN</sub> = 40.2 kHz, −0.02 dBFS                   | −86                       | −74                   | dB (max)   |
| SFDR                                | Spurious-Free Dynamic Range                    | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>IN</sub> = 40.2 kHz, −0.02 dBFS                   | 88                        | 75.6                  | dB (min)   |
| ENOB                                | Effective Number of Bits                       | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,                                                             | 11.8                      | 11.3                  | Bits (min) |
|                                     | Channel-to-Channel Crosstalk                   | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>IN</sub> = 40.2 kHz                               | −82                       |                       | dB         |
| IMD                                 | Intermodulation Distortion, Second Order Terms | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>a</sub> = 40.161 kHz, f <sub>b</sub> = 41.015 kHz | −93                       |                       | dB         |
|                                     | Intermodulation Distortion, Third Order Terms  | AV <sub>DD</sub> = +5.0V, DV <sub>DD</sub> = +3.0V,<br>f <sub>a</sub> = 40.161 kHz, f <sub>b</sub> = 41.015 kHz | −90                       |                       | dB         |
| FPBW                                | −3 dB Full Power Bandwidth                     | AV <sub>DD</sub> = +5V                                                                                          | 11                        |                       | MHz        |
|                                     |                                                | AV <sub>DD</sub> = +3V                                                                                          | 8                         |                       | MHz        |
| ANALOG INPUT CHARACTERISTICS        |                                                |                                                                                                                 |                           |                       |            |
| V <sub>IN</sub>                     | Input Range                                    |                                                                                                                 | 0 to AV <sub>DD</sub>     |                       | V          |
| I <sub>DCL</sub>                    | DC Leakage Current                             |                                                                                                                 |                           | ±1                    | μA (max)   |
| C <sub>INA</sub>                    | Input Capacitance                              | Track Mode                                                                                                      | 33                        |                       | pF         |
|                                     |                                                | Hold Mode                                                                                                       | 3                         |                       | pF         |
| DIGITAL INPUT CHARACTERISTICS       |                                                |                                                                                                                 |                           |                       |            |
| V <sub>IH</sub>                     | Input High Voltage                             | DV <sub>DD</sub> = +4.75Vto +5.25V                                                                              |                           | 2.4                   | V (min)    |
|                                     |                                                | DV <sub>DD</sub> = +2.7V to +3.6V                                                                               |                           | 2.1                   | V (min)    |
| V <sub>IL</sub>                     | Input Low Voltage                              | DV <sub>DD</sub> = +2.7V to +5.25V                                                                              |                           | 0.8                   | V (max)    |
| I <sub>IN</sub>                     | Input Current                                  | V <sub>IN</sub> = 0V or DV <sub>DD</sub>                                                                        | ±0.01                     | ±1                    | μA (max)   |
| C <sub>IND</sub>                    | Digital Input Capacitance                      |                                                                                                                 | 2                         | 4                     | pF (max)   |
| DIGITAL OUTPUT CHARACTERISTICS      |                                                |                                                                                                                 |                           |                       |            |
| V <sub>OH</sub>                     | Output High Voltage                            | I <sub>SOURCE</sub> = 200 μA, DV <sub>DD</sub> = +2.7V to +5.25V                                                |                           | DV <sub>DD</sub> −0.5 | V (min)    |
| V <sub>OL</sub>                     | Output Low Voltage                             | I <sub>SINK</sub> = 200 μA                                                                                      |                           | 0.4                   | V (max)    |
| I <sub>OZH</sub> , I <sub>OZL</sub> | TRI-STATE® Leakage Current                     |                                                                                                                 |                           | ±1                    | μA (max)   |
| C <sub>OUT</sub>                    | TRI-STATE® Output Capacitance                  |                                                                                                                 | 2                         | 4                     | pF (max)   |
|                                     | Output Coding                                  |                                                                                                                 | Straight (Natural) Binary |                       |            |

(1) Data sheet min/max specification limits are ensured by design, test, or statistical analysis.

(2) Tested limits are specified to TI's AOQL (Average Outgoing Quality Level).

## ADC78H90 Converter Electrical Characteristics <sup>(1)</sup> (continued)

The following specifications apply for  $AV_{DD} = DV_{DD} = +2.7V$  to  $5.25V$ ,  $AGND = DGND = 0V$ ,  $f_{SCLK} = 8\text{ MHz}$ ,  $f_{SAMPLE} = 500\text{ KSPS}$ , unless otherwise noted. **Boldface limits apply for  $T_A = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = 25^\circ C$ .

| Symbol                                                | Parameter                                                               | Conditions                                                                                                          | Typical | Limits<br>(2) | Units       |
|-------------------------------------------------------|-------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|---------|---------------|-------------|
| POWER SUPPLY CHARACTERISTICS (C <sub>L</sub> = 10 pF) |                                                                         |                                                                                                                     |         |               |             |
| AV <sub>DD</sub> ,<br>DV <sub>DD</sub>                | Analog and Digital Supply Voltages                                      | AV <sub>DD</sub> ≥ DV <sub>DD</sub>                                                                                 |         | 2.7           | V (min)     |
|                                                       |                                                                         |                                                                                                                     |         | 5.25          | V (max)     |
| I <sub>A</sub> + I <sub>D</sub>                       | Total Supply Current, Normal Mode<br>(Operational, $\overline{CS}$ low) | AV <sub>DD</sub> = DV <sub>DD</sub> = +4.75V to +5.25V,<br>f <sub>SAMPLE</sub> = 500 kSPS, f <sub>IN</sub> = 40 kHz | 1.65    | 2.3           | mA (max)    |
|                                                       |                                                                         | AV <sub>DD</sub> = DV <sub>DD</sub> = +2.7V to +3.6V,<br>f <sub>SAMPLE</sub> = 500 kSPS, f <sub>IN</sub> = 40 kHz   | 0.5     | 2.3           | mA (max)    |
|                                                       | Total Supply Current, Shutdown ( $\overline{CS}$ high)                  | AV <sub>DD</sub> = DV <sub>DD</sub> = +4.75V to +5.25V,<br>f <sub>SAMPLE</sub> = 0 kSPS                             | 200     |               | nA          |
|                                                       |                                                                         | AV <sub>DD</sub> = DV <sub>DD</sub> = +2.7V to +3.6V,<br>f <sub>SAMPLE</sub> = 0 kSPS                               | 200     |               | nA          |
| P <sub>D</sub>                                        | Power Consumption, Normal Mode<br>(Operational, $\overline{CS}$ low)    | AV <sub>DD</sub> = DV <sub>DD</sub> = +4.75V to +5.25V                                                              | 8.3     | 12            | mW (max)    |
|                                                       |                                                                         | AV <sub>DD</sub> = DV <sub>DD</sub> = +2.7V to +3.6V                                                                | 1.5     | 8.3           | mW (max)    |
|                                                       | Power Consumption, Shutdown ( $\overline{CS}$ high)                     | AV <sub>DD</sub> = DV <sub>DD</sub> = +4.75V to +5.25V                                                              | 0.5     |               | μW          |
|                                                       |                                                                         | AV <sub>DD</sub> = DV <sub>DD</sub> = +2.7V to +3.6V                                                                | 0.3     |               | μW          |
| AC ELECTRICAL CHARACTERISTICS                         |                                                                         |                                                                                                                     |         |               |             |
| f <sub>SCLK</sub>                                     | Maximum Clock Frequency                                                 |                                                                                                                     |         | 8             | MHz (min)   |
| f <sub>SMIN</sub>                                     | Minimum Clock Frequency                                                 |                                                                                                                     | 50      |               | kHz         |
| f <sub>S</sub>                                        | Maximum Sample Rate                                                     |                                                                                                                     |         | 500           | KSPS (min)  |
| t <sub>CONV</sub>                                     | Conversion Time                                                         |                                                                                                                     |         | 13            | SCLK cycles |
| DC                                                    | SCLK Duty Cycle                                                         |                                                                                                                     | 50      | 40            | % (min)     |
|                                                       |                                                                         |                                                                                                                     |         | 60            | % (max)     |
| t <sub>ACQ</sub>                                      | Track/Hold Acquisition Time                                             | Full-Scale Step Input                                                                                               |         | 3             | SCLK cycles |
|                                                       | Throughput Time                                                         | Acquisition Time + Conversion Time                                                                                  |         | 16            | SCLK cycles |
| f <sub>RATE</sub>                                     | Throughput Rate                                                         |                                                                                                                     |         | 500           | kSPS (min)  |
| t <sub>AD</sub>                                       | Aperture Delay                                                          |                                                                                                                     | 4       |               | ns          |

## ADC78H90 Timing Specifications

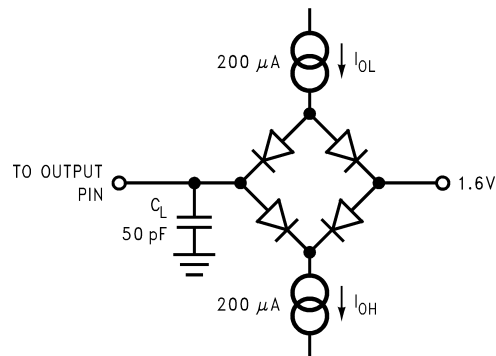
The following specifications apply for  $AV_{DD} = DV_{DD} = +2.7V$  to  $5.25V$ ,  $AGND = DGND = 0V$ ,  $f_{SCLK} = 8\text{ MHz}$ ,  $f_{SAMPLE} = 500\text{ KSPS}$ ,  $C_L = 50\text{ pF}$ , **Boldface limits apply for  $T_A = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = 25^\circ C$ .

| Symbol   | Parameter                                            | Conditions | Typical | Limits <sup>(1)</sup>              | Units    |
|----------|------------------------------------------------------|------------|---------|------------------------------------|----------|
| $t_{1a}$ | Setup Time SCLK High to $\overline{CS}$ Falling Edge | (2)        |         | <b>10</b>                          | ns (min) |
| $t_{1b}$ | Hold time SCLK Low to $\overline{CS}$ Falling Edge   | (2)        |         | <b>10</b>                          | ns (min) |
| $t_2$    | Delay from $\overline{CS}$ Until DOUT active         |            |         | <b>30</b>                          | ns (max) |
| $t_3$    | Data Access Time after SCLK Falling Edge             |            |         | <b>30</b>                          | ns (max) |
| $t_4$    | Data Setup Time Prior to SCLK Rising Edge            |            |         | <b>10</b>                          | ns (min) |
| $t_5$    | Data Valid SCLK Hold Time                            |            |         | <b>10</b>                          | ns (min) |
| $t_6$    | SCLK High Pulse Width                                |            |         | <b>0.4 x <math>t_{SCLK}</math></b> | ns (min) |
| $t_7$    | SCLK Low Pulse Width                                 |            |         | <b>0.4 x <math>t_{SCLK}</math></b> | ns (min) |
| $t_8$    | $\overline{CS}$ Rising Edge to DOUT High-Impedance   |            |         | <b>20</b>                          | ns (max) |

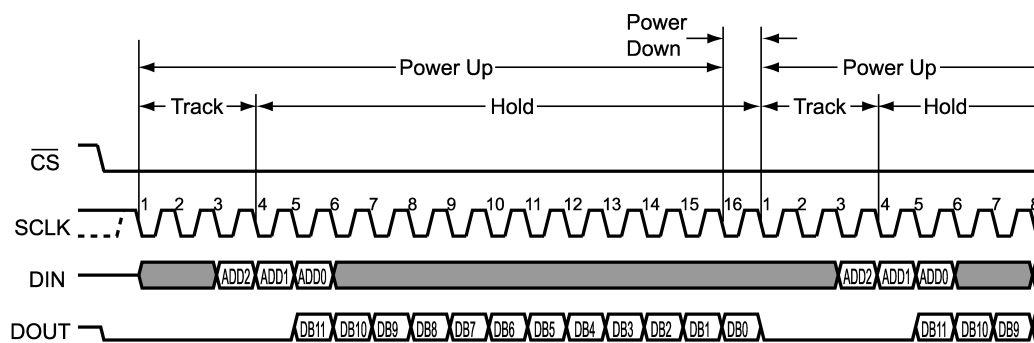
(1) Tested limits are specified to TI's AOQL (Average Outgoing Quality Level).

(2) Clock may be in any state (high or low) when  $\overline{CS}$  is asserted, with the restrictions on setup and hold time given by  $t_{1a}$  and  $t_{1b}$ .

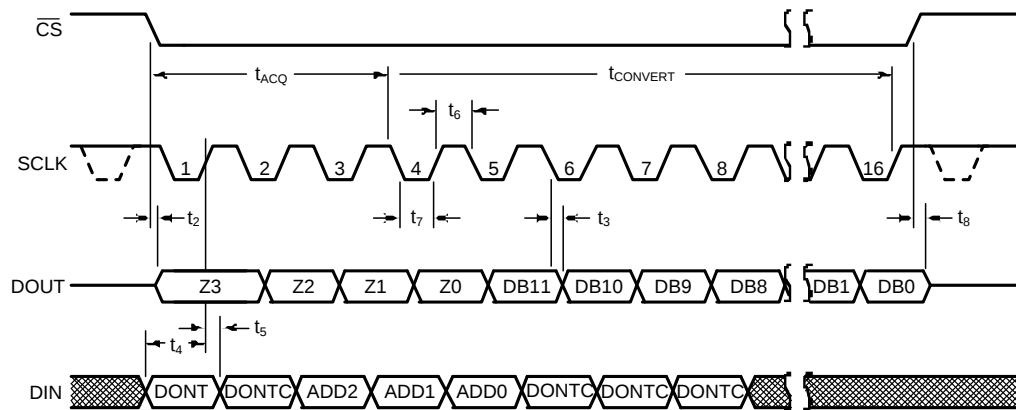
## Timing Diagrams



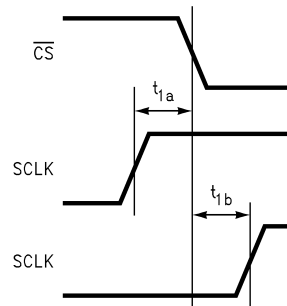
**Figure 2. Timing Test Circuit**



**Figure 3. ADC78H90 Operational Timing Diagram**



**Figure 4. ADC78H90 Serial Timing Diagram**



**Figure 5. SCLK and  $\overline{\text{CS}}$  Timing Parameters**

## Specification Definitions

**ACQUISITION TIME** is the time required to acquire the input voltage. That is, it is time required for the hold capacitor to charge up to the input voltage.

**APERTURE DELAY** is the time between the fourth falling SCLK edge of a conversion and the time when the input signal is acquired or held for conversion.

**CONVERSION TIME** is the time required, after the input voltage is acquired, for the ADC to convert the input voltage to a digital word.

**CROSSTALK** is the coupling of energy from one channel into the other channel, or the amount of signal energy from one analog input that appears at the measured analog input.

**DIFFERENTIAL NON-LINEARITY (DNL)** is the measure of the maximum deviation from the ideal step size of 1 LSB.

**DUTY CYCLE** is the ratio of the time that a repetitive digital waveform is high to the total time of one period. The specification here refers to the SCLK.

**EFFECTIVE NUMBER OF BITS (ENOB, or EFFECTIVE BITS)** is another method of specifying Signal-to-Noise and Distortion or SINAD. ENOB is defined as  $(\text{SINAD} - 1.76) / 6.02$  and says that the converter is equivalent to a perfect ADC of this (ENOB) number of bits

**FULL POWER BANDWIDTH** is a measure of the frequency at which the reconstructed output fundamental drops 3 dB below its low frequency value for a full scale input.

**GAIN ERROR** is the deviation of the last code transition (111...110) to (111...111) from the ideal ( $V_{\text{REF}} - 1.5$  LSB), after adjusting for offset error.

**INTEGRAL NON-LINEARITY (INL)** is a measure of the deviation of each individual code from a line drawn from negative full scale ( $\frac{1}{2}$  LSB below the first code transition) through positive full scale ( $\frac{1}{2}$  LSB above the last code transition). The deviation of any given code from this straight line is measured from the center of that code value.

**INTERMODULATION DISTORTION (IMD)** is the creation of additional spectral components as a result of two sinusoidal frequencies being applied to the ADC input at the same time. It is defined as the ratio of the power in the second and third order intermodulation products to the sum of the power in both of the original frequencies. IMD is usually expressed in dB.

**MISSING CODES** are those output codes that will never appear at the ADC outputs. The ADC78H90 is ensured not to have any missing codes.

**OFFSET ERROR** is the deviation of the first code transition (000...000) to (000...001) from the ideal (i.e. GND + 0.5 LSB).

**SIGNAL TO NOISE RATIO (SNR)** is the ratio, expressed in dB, of the rms value of the input signal to the rms value of the sum of all other spectral components below one-half the sampling frequency, not including harmonics or d.c.

**SIGNAL TO NOISE PLUS DISTORTION (S/N+D or SINAD)** Is the ratio, expressed in dB, of the rms value of the input signal to the rms value of all of the other spectral components below half the clock frequency,

including harmonics but excluding d.c.

**SPURIOUS FREE DYNAMIC RANGE (SFDR)** is the difference, expressed in dB, between the rms values of the input signal and the peak spurious signal where a spurious signal is any signal present in the output spectrum that is not present at the input, excluding d.c.

**TOTAL HARMONIC DISTORTION (THD)** is the ratio, expressed in dB or dBc, of the rms total of the first five harmonic components at the output to the rms level of the input signal frequency as seen at the output. THD is calculated as

$$\text{THD} = 20 \cdot \log_{10} \sqrt{\frac{A_{f2}^2 + \dots + A_{f6}^2}{A_{f1}^2}}$$

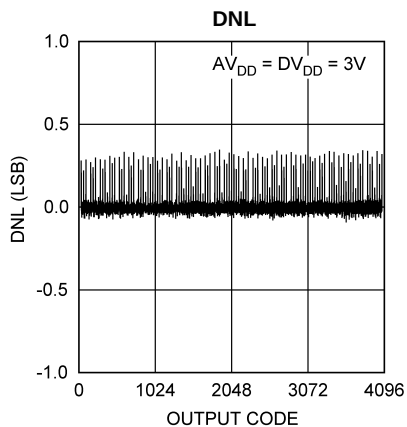
where

- $A_{f1}$  is the RMS power of the input frequency at the output
  - $A_{f2}$  through  $A_{f6}$  are the RMS power in the first 5 harmonic frequencies
- (1)

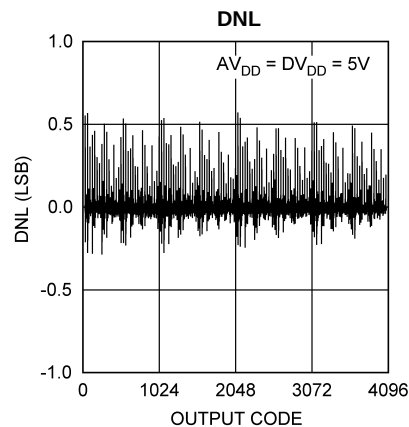
**THROUGHPUT TIME** is the minimum time required between the start of two successive conversion. It is the acquisition time plus the conversion time. In the case of the ADC78H90, this is 16 SCLK periods.

## Typical Performance Characteristics

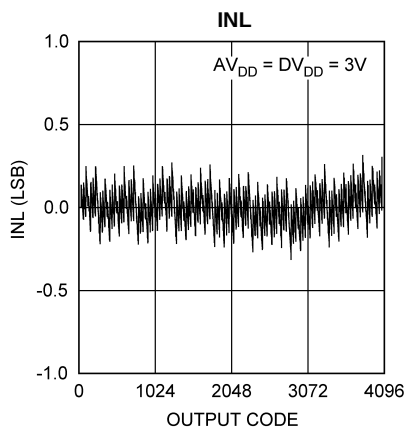
$T_A = +25^\circ\text{C}$ ,  $f_{\text{SAMPLE}} = 500 \text{ kSPS}$ ,  $f_{\text{SCLK}} = 8 \text{ MHz}$ ,  $f_{\text{IN}} = 40.2 \text{ kHz}$  unless otherwise stated.



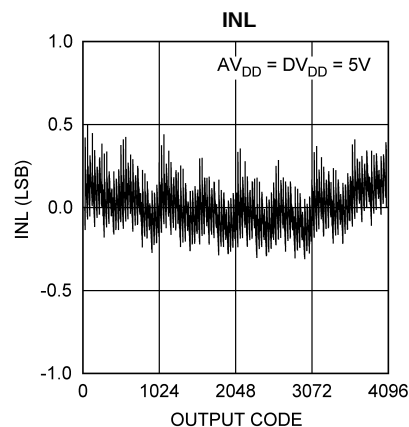
**Figure 6.**



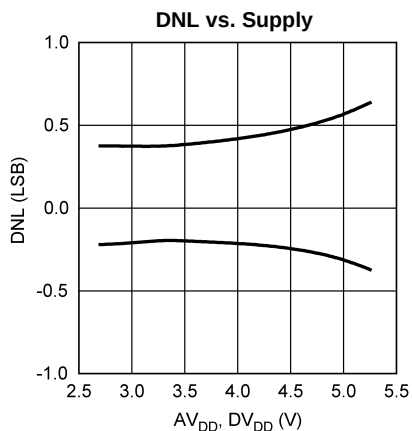
**Figure 7.**



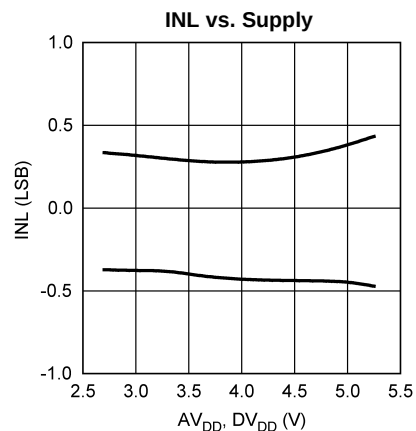
**Figure 8.**



**Figure 9.**



**Figure 10.**



**Figure 11.**

### Typical Performance Characteristics (continued)

$T_A = +25^\circ\text{C}$ ,  $f_{\text{SAMPLE}} = 500 \text{ kSPS}$ ,  $f_{\text{SCLK}} = 8 \text{ MHz}$ ,  $f_{\text{IN}} = 40.2 \text{ kHz}$  unless otherwise stated.

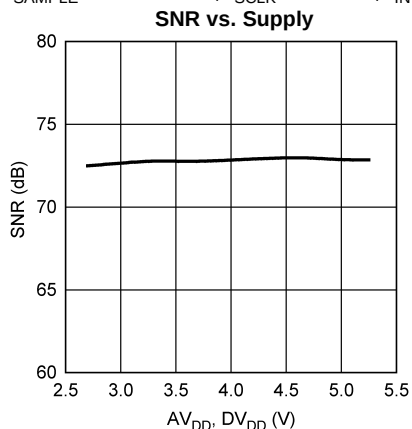


Figure 12.

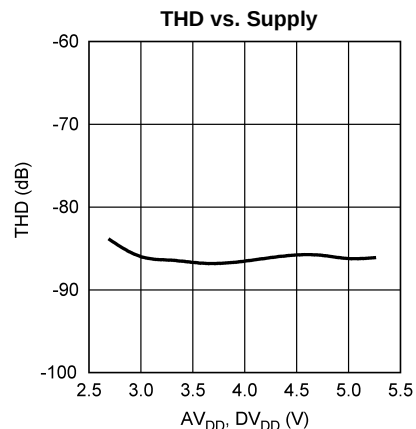


Figure 13.

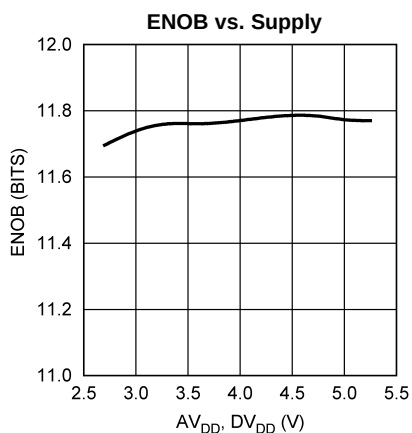


Figure 14.

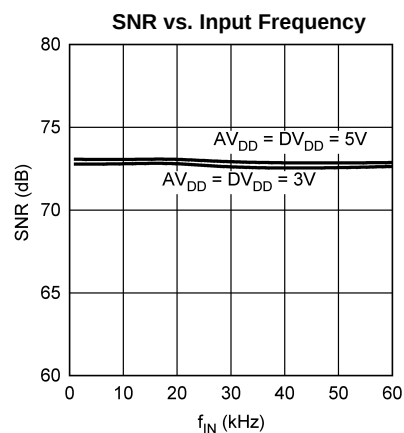


Figure 15.

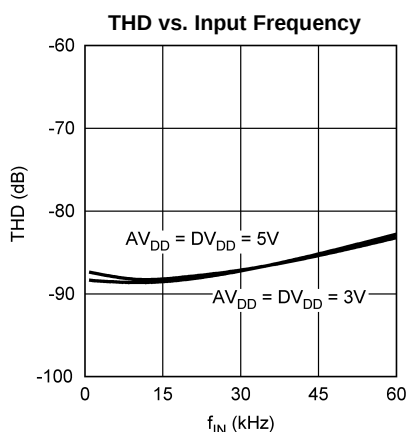


Figure 16.

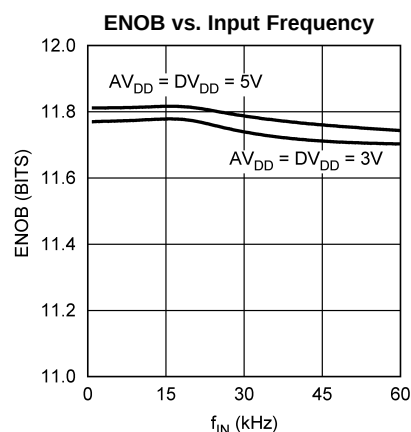


Figure 17.

## Typical Performance Characteristics (continued)

$T_A = +25^\circ\text{C}$ ,  $f_{\text{SAMPLE}} = 500 \text{ kSPS}$ ,  $f_{\text{SCLK}} = 8 \text{ MHz}$ ,  $f_{\text{IN}} = 40.2 \text{ kHz}$  unless otherwise stated.

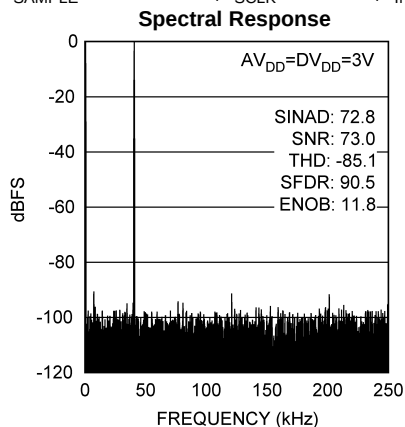


Figure 18.

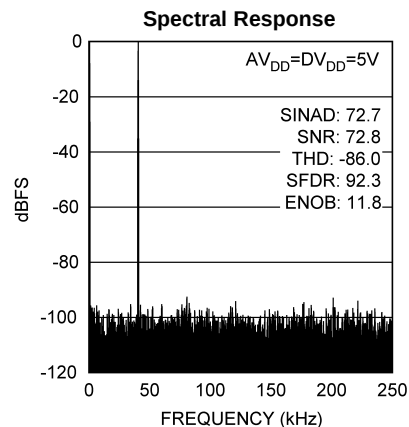


Figure 19.

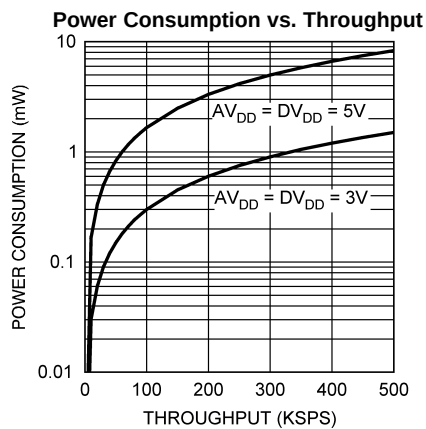


Figure 20.

## APPLICATIONS INFORMATION

### ADC78H90 OPERATION

The ADC78H90 is a successive-approximation analog-to-digital converter designed around a charge-redistribution digital-to-analog converter. Simplified schematics of the ADC78H90 in both track and hold operation are shown in Figure 21 and Figure 22, respectively. In Figure 21, the ADC78H90 is in track mode: switch SW1 connects the sampling capacitor to one of eight analog input channels through the multiplexer, and SW2 balances the comparator inputs. The ADC78H90 is in this state for the first three SCLK cycles after  $\overline{CS}$  is brought low.

There is no power-up delay or dummy conversions with the ADC78H90. The ADC is able to sample and convert an input to full resolution in the first conversion immediately following power up. The first conversion result after power up will be that of the first channel.

Figure 22 shows the ADC78H90 in hold mode: switch SW1 connects the sampling capacitor to ground, maintaining the sampled voltage, and switch SW2 unbalances the comparator. The control logic then instructs the charge-redistribution DAC to add or subtract fixed amounts of charge to or from the sampling capacitor until the comparator is balanced. When the comparator is balanced, the digital word supplied to the DAC is the digital representation of the analog input voltage. The ADC78H90 is in this state for the last thirteen SCLK cycles after  $\overline{CS}$  is brought low.

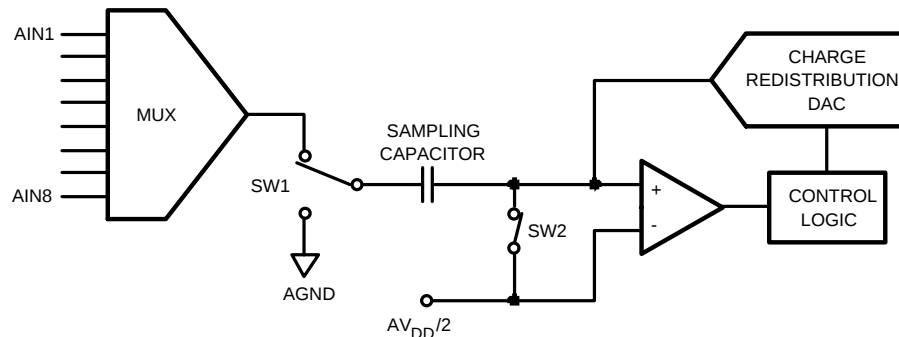


Figure 21. ADC78H90 in Track Mode

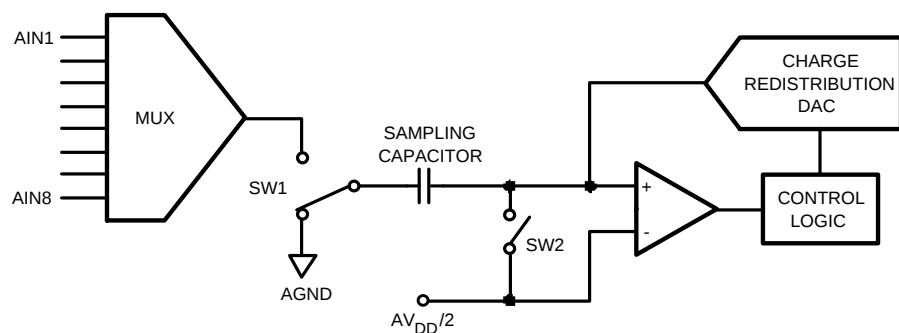


Figure 22. ADC78H90 in Hold Mode

The time when  $\overline{CS}$  is low is considered a serial frame. Each of these frames should contain an integer multiple of 16 SCLK cycles, during which time a conversion is performed and clocked out at the DOUT pin and data is clocked into the DIN pin to indicate the multiplexer address for the next conversion.

## USING THE ADC78H90

Figure 3 and Figure 4 for the ADC78H90 are shown in [Timing Diagrams](#).  $\overline{CS}$ , chip select, initiates conversions and frames the serial data transfers. SCLK (serial clock) controls both the conversion process and the timing of serial data. DOUT is the serial data output pin, where a conversion result is sent as a serial data stream, MSB first. Data to be written to the ADC78H90's Control Register is placed on DIN, the serial data input pin. New data is written to DIN with each conversion.

A serial frame is initiated on the falling edge of  $\overline{CS}$  and ends on the rising edge of  $\overline{CS}$ . Each frame must contain an integer multiple of 16 rising SCLK edges. The ADC output data (DOUT) is in a high impedance state when  $\overline{CS}$  is high and is active when  $\overline{CS}$  is low. Thus,  $\overline{CS}$  acts as an output enable. Additionally, the device goes into a power down state when  $\overline{CS}$  is high.

During the first 3 cycles of SCLK, the ADC is in the track mode, acquiring the input voltage. For the next 13 SCLK cycles the conversion is accomplished and the data is clocked out, MSB first. If there is more than one conversion in a frame, the ADC will re-enter the track mode on the falling edge of SCLK after the N\*16th rising edge of SCLK, and re-enter the hold/convert mode on the N\*16+4th falling edge of SCLK, where "N" must be an integer.

When  $\overline{CS}$  is brought high, SCLK is internally gated off. If SCLK is in a low state when  $\overline{CS}$  goes high, the subsequent fall of  $\overline{CS}$  will generate a falling edge of the internal version of SCLK, putting the ADC into the track mode. This is seen by the ADC as the first falling edge of SCLK. If SCLK is in a high state when  $\overline{CS}$  goes high, the ADC enters the track mode on the first falling edge of SCLK after the falling edge of  $\overline{CS}$ .

During each conversion, data is clocked into the DIN pin on the first 8 rising edges of SCLK after the fall of  $\overline{CS}$ . For each conversion, it is necessary to clock in the data indicating the input that is selected for the conversion after the current one. See [Table 1](#), [Table 2](#), and [Table 3](#).

If  $\overline{CS}$  and SCLK go low simultaneously, it is the following rising edge of SCLK that is considered the first rising edge for clocking data into DIN.

**Table 1. Control Register Bits**

| Bit 7 (MSB) | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------------|-------|-------|-------|-------|-------|-------|-------|
| DONTC       | DONTC | ADD2  | ADD1  | ADD0  | DONTC | DONTC | DONTC |

**Table 2. Control Register Bit Descriptions**

| Bit #:        | Symbol: | Description                                                                                                                                                                                             |
|---------------|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7, 6, 2, 1, 0 | DONTC   | Don't care. The value of these bit do not affect the device.                                                                                                                                            |
| 5             | ADD2    | These three bits determine which input channel will be sampled and converted on the next falling edge of $\overline{CS}$ . The mapping between codes and channels is shown in <a href="#">Table 3</a> . |
| 4             | ADD1    |                                                                                                                                                                                                         |
| 3             | ADD0    |                                                                                                                                                                                                         |

**Table 3. Input Channel Selection**

| ADD2 | ADD1 | ADD0 | Input Channel  |
|------|------|------|----------------|
| 0    | 0    | 0    | AIN1 (Default) |
| 0    | 0    | 1    | AIN2           |
| 0    | 1    | 0    | AIN3           |
| 0    | 1    | 1    | AIN4           |
| 1    | 0    | 0    | AIN5           |
| 1    | 0    | 1    | AIN6           |
| 1    | 1    | 0    | AIN7           |
| 1    | 1    | 1    | AIN8           |

## ADC78H90 TRANSFER FUNCTION

The output format of the ADC78H90 is straight binary. Code transitions occur midway between successive integer LSB values. The LSB width for the ADC78H90 is  $AV_{DD} / 4096$ . The ideal transfer characteristic is shown in Figure 23. The transition from an output code of 0000 0000 0000 to a code of 0000 0000 0001 is at  $1/2$  LSB, or a voltage of  $AV_{DD} / 8192$ . Other code transitions occur at steps of one LSB.

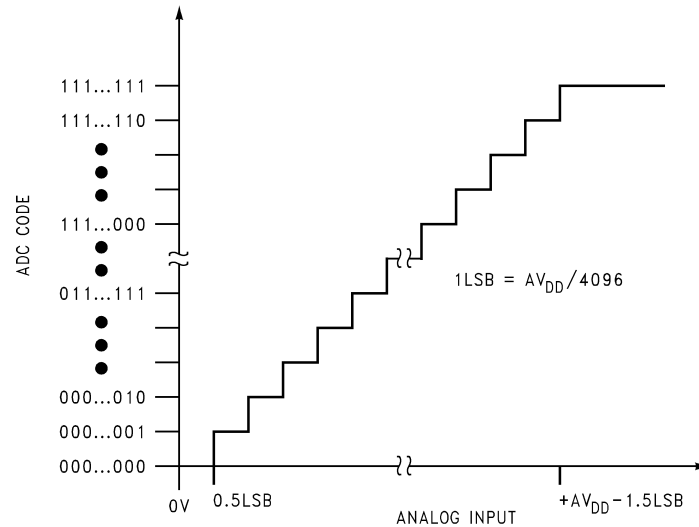


Figure 23. Ideal Transfer Characteristic

## TYPICAL APPLICATION CIRCUIT

A typical application of the ADC78H90 is shown in Figure 24. The split analog and digital supplies are both provided in this example by the TI LP2950 low-dropout voltage regulator, available in a variety of fixed and adjustable output voltages. The analog supply is bypassed with a capacitor network located close to the ADC78H90. The digital supply is separated from the analog supply by an isolation resistor and conditioned with additional bypass capacitors. The ADC78H90 uses the analog supply ( $AV_{DD}$ ) as its reference voltage, so it is very important that  $AV_{DD}$  be kept as clean as possible. Because of the ADC78H90's low power requirements, it is also possible to use a precision reference as a power supply to maximize performance. The four-wire interface is also shown connected to a microprocessor or DSP.

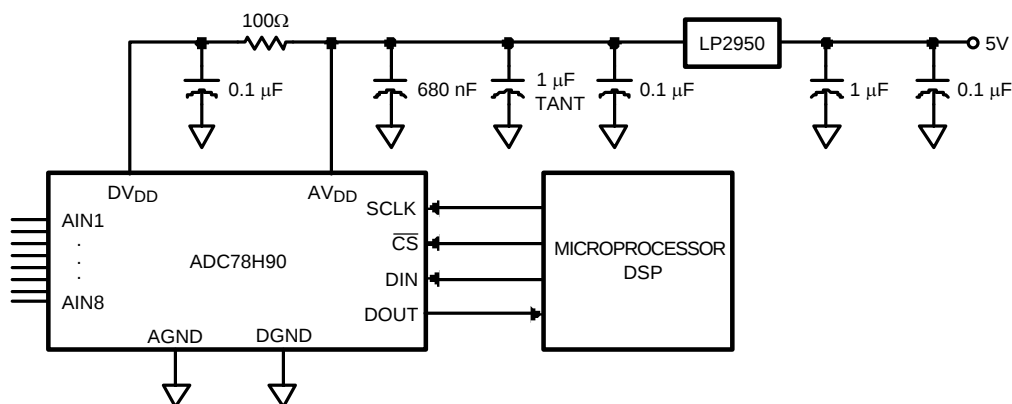


Figure 24. Typical Application Circuit

## ANALOG INPUTS

An equivalent circuit for one of the ADC78H90's input channels is shown in Figure 25. Diodes D1 and D2 provide ESD protection for the analog inputs. At no time should an analog input go beyond ( $AV_{DD} + 300\text{ mV}$ ) or ( $GND - 300\text{ mV}$ ), as these ESD diodes will begin conducting, which could result in erratic operation.

The capacitor C1 in Figure 25 has a typical value of 3 pF, and is mainly the package pin capacitance. Resistor R1 is the on resistance of the multiplexer and track / hold switch, and is typically 500 ohms. Capacitor C2 is the ADC78H90 sampling capacitor, and is typically 30 pF. The ADC78H90 will deliver best performance when driven by a low-impedance source to eliminate distortion caused by the charging of the sampling capacitance. This is especially important when using the ADC78H90 to sample AC signals. Also important when sampling dynamic signals is a band-pass or low-pass filter to reduce harmonics and noise, improving dynamic performance.

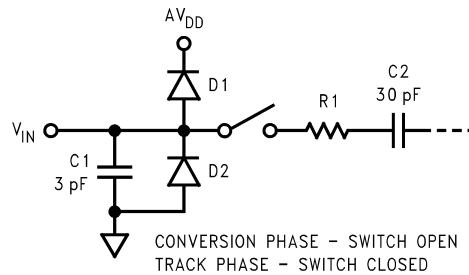


Figure 25. Equivalent Input Circuit

## DIGITAL INPUTS AND OUTPUTS

The ADC78H90's digital inputs (SCLK,  $\overline{CS}$ , and DIN) are limited by and cannot exceed the analog supply voltage  $AV_{DD}$ . The digital input pins are not prone to latch-up; SCLK,  $\overline{CS}$ , and DIN may be asserted before  $DV_{DD}$  without any risk.

## POWER SUPPLY CONSIDERATIONS

The ADC78H90 has two supplies, although they could both have the same potential. There are two major power supply concerns with this product. They are relative power supply levels, including power on sequencing, and the effect of digital supply noise on the analog supply.

### Power Management

The ADC78H90 is a dual-supply device. These two supplies share ESD resources, and thus care must be exercised to ensure that the power supplies are applied in the correct sequence. To avoid turning on the ESD diodes, the digital supply ( $DV_{DD}$ ) cannot exceed the analog supply ( $AV_{DD}$ ) by more than 300 mV. The ADC78H90's analog power supply must, therefore, be applied before (or concurrently with) the digital power supply.

The ADC78H90 is fully powered-up whenever  $\overline{CS}$  is low, and fully powered-down whenever  $\overline{CS}$  is high, with one exception: the ADC78H90 automatically enters power-down mode between the 16th falling edge of a conversion and the 1st falling edge of the subsequent conversion (see Figure 3).

The ADC78H90 can perform multiple conversions back to back; each conversion requires 16 SCLK cycles. The ADC78H90 will perform conversions continuously as long as  $\overline{CS}$  is held low.

The user may trade off throughput for power consumption by simply performing fewer conversions per unit time. Figure 20 in Typical Performance Characteristics shows the typical power consumption of the ADC78H90 versus throughput. To calculate the power consumption, simply multiply the fraction of time spent in the normal mode by the normal mode power consumption (8.3 mW with  $AV_{DD} = DV_{DD} = +3.6\text{V}$ , for example), and add the fraction of time spent in shutdown mode multiplied by the shutdown mode power dissipation (0.3 mW with  $AV_{DD} = DV_{DD} = +3.6\text{V}$ ).

## Power Supply Noise Considerations

The charging of any output load capacitance requires current from the digital supply,  $DV_{DD}$ . The current pulses required from the supply to charge the output capacitance will cause voltage variations on the digital supply. If these variations are large enough, they could cause degrade SNR and SINAD performance of the ADC. Furthermore, if the analog and digital supplies are tied directly together, the noise on the digital supply will be coupled directly into the analog supply, causing greater performance degradation than noise on the digital supply. Furthermore, discharging the output capacitance when the digital output goes from a logic high to a logic low will dump current into the die substrate, which is resistive. Load discharge currents will cause "ground bounce" noise in the substrate that will degrade noise performance if that current is large enough. The larger is the output capacitance, the more current flows through the die substrate and the greater is the noise coupled into the analog channel, degrading noise performance.

The first solution is to decouple the analog and digital supplies from each other, or use separate supplies for them, to keep digital noise out of the analog supply. To keep noise out of the digital supply, keep the output load capacitance as small as practical. If the load capacitance is greater than 25 pF, use a 100  $\Omega$  series resistor at the ADC output, located as close to the ADC output pin as practical. This will limit the charge and discharge current of the output capacitance and improve noise performance.

## REVISION HISTORY

| Changes from Revision C (March 2013) to Revision D         | Page               |
|------------------------------------------------------------|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">16</a> |

## PACKAGING INFORMATION

| Orderable Device   | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|--------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| ADC78H90CIMT       | NRND          | TSSOP        | PW                 | 16   |                | TBD                        | Call TI                 | Call TI              | -40 to 85    | 78H90<br>CIMT           |                         |
| ADC78H90CIMT/NOPB  | ACTIVE        | TSSOP        | PW                 | 16   | 92             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 85    | 78H90<br>CIMT           | <a href="#">Samples</a> |
| ADC78H90CIMTX/NOPB | ACTIVE        | TSSOP        | PW                 | 16   | 2500           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-260C-UNLIM   | -40 to 85    | 78H90<br>CIMT           | <a href="#">Samples</a> |

(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.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**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.

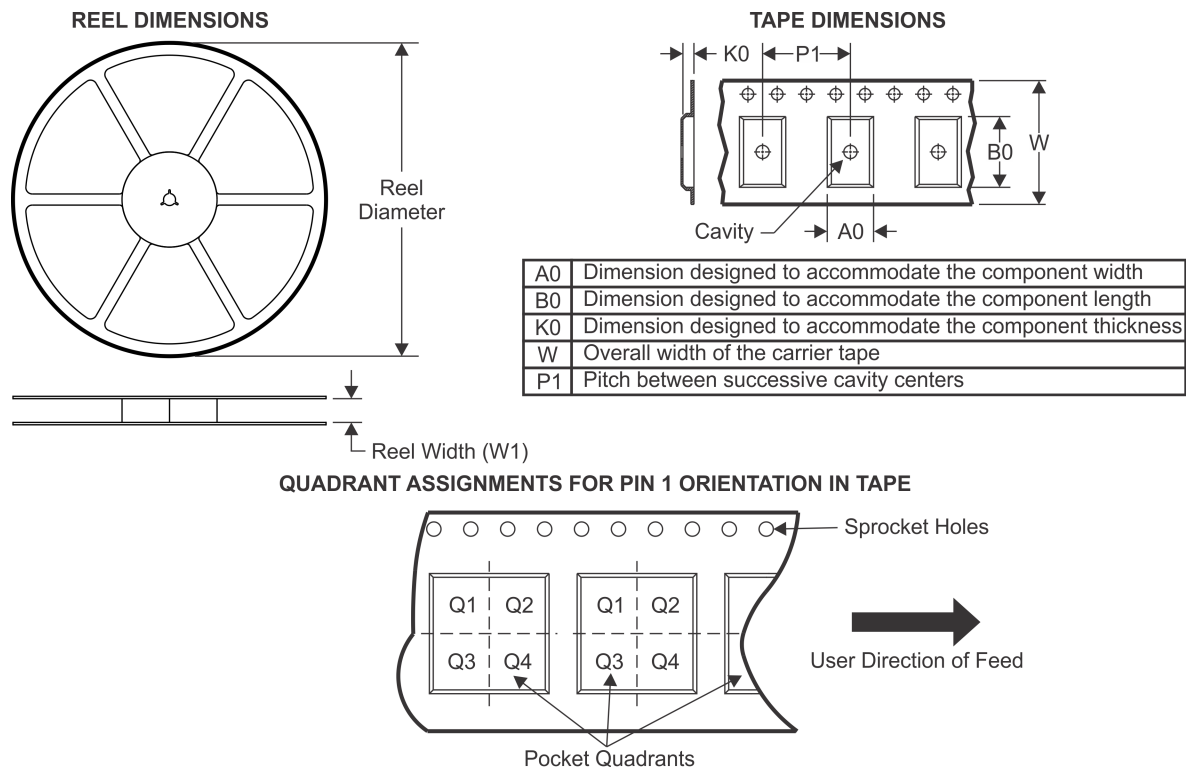
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(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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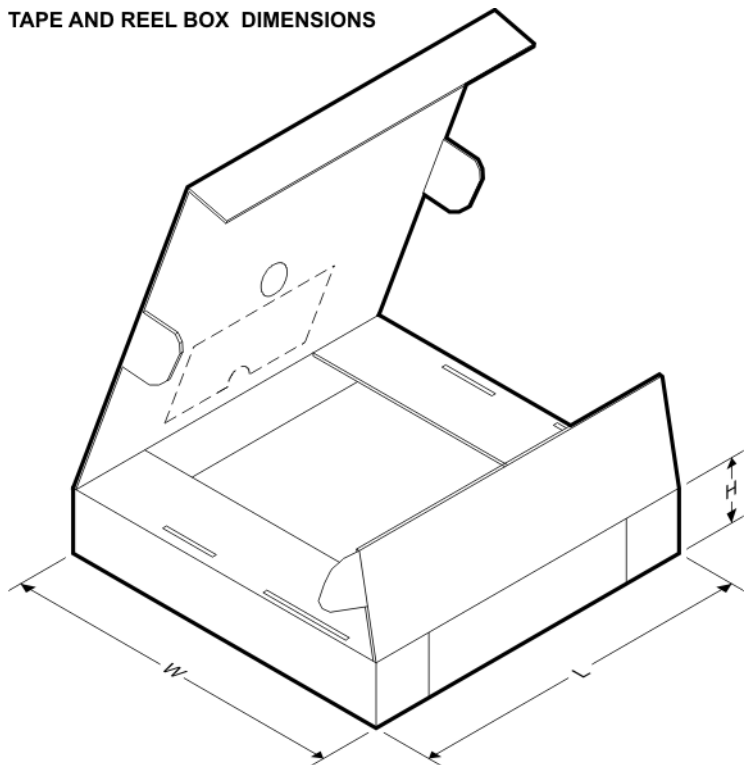
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**TAPE AND REEL INFORMATION**


\*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 |
|--------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| ADC78H90C1MTX/NOPB | TSSOP        | PW              | 16   | 2500 | 330.0              | 12.4               | 6.95    | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS

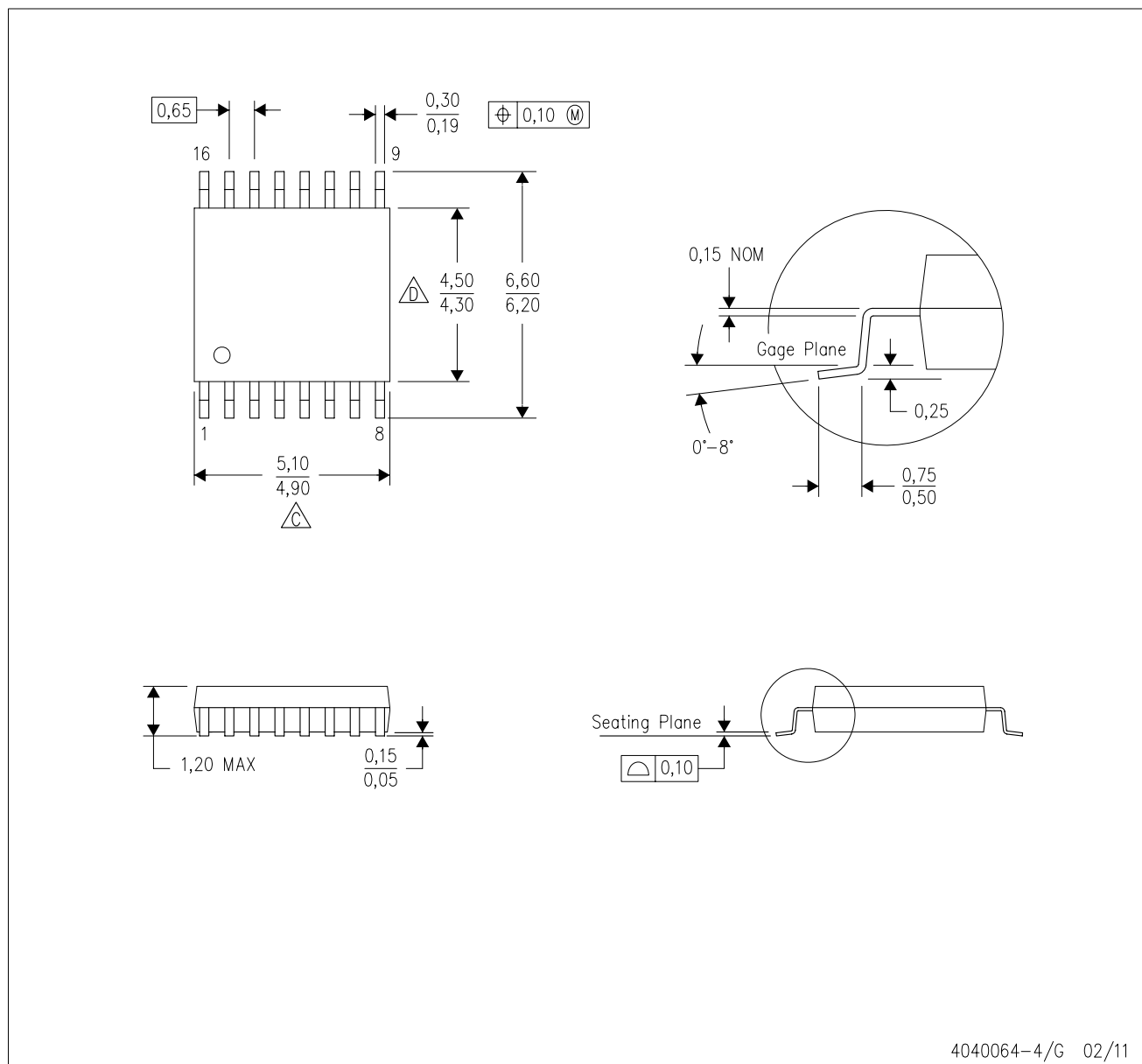


\*All dimensions are nominal

| Device             | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| ADC78H90CIMTX/NOPB | TSSOP        | PW              | 16   | 2500 | 367.0       | 367.0      | 35.0        |

PW (R-PDSO-G16)

PLASTIC SMALL OUTLINE



4040064-4/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - 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 each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

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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.

### Products

|                              |                                                                                      |
|------------------------------|--------------------------------------------------------------------------------------|
| Audio                        | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                               |
| Amplifiers                   | <a href="http://amplifier.ti.com">amplifier.ti.com</a>                               |
| Data Converters              | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>                       |
| DLP® Products                | <a href="http://www.dlp.com">www.dlp.com</a>                                         |
| DSP                          | <a href="http://dsp.ti.com">dsp.ti.com</a>                                           |
| Clocks and Timers            | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
| Interface                    | <a href="http://interface.ti.com">interface.ti.com</a>                               |
| Logic                        | <a href="http://logic.ti.com">logic.ti.com</a>                                       |
| Power Mgmt                   | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers             | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                         | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Applications Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
| Wireless Connectivity        | <a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a> |

### Applications

|                               |                                                                                          |
|-------------------------------|------------------------------------------------------------------------------------------|
| Automotive and Transportation | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>                         |
| Communications and Telecom    | <a href="http://www.ti.com/communications">www.ti.com/communications</a>                 |
| Computers and Peripherals     | <a href="http://www.ti.com/computers">www.ti.com/computers</a>                           |
| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
| Medical                       | <a href="http://www.ti.com/medical">www.ti.com/medical</a>                               |
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