



# LC<sup>2</sup>MOS LOGDAC Logarithmic D/A Converter

## AD7111/AD7111A

### FEATURES

**Dynamic Range: 88.5 dB**

**Resolution: 0.375 dB**

**On-Chip Data Latches**

**+5 V Operation**

**AD7111A Pin Compatible with AD7524**

**Low Power**

### APPLICATIONS

**Audio Attenuators**

**Sonar Systems**

**Function Generators**

**Digitally Controlled AGC System**

### GENERAL DESCRIPTION

The LOGDAC® AD7111/AD7111A are monolithic multiplying D/A converters featuring wide dynamic range in a small package. Both DACs can attenuate an analog input signal over the range 0 dB to 88.5 dB in 0.375 dB steps. They are available in 16-pin DIPs and SOIC packages. The AD7111 is also available in a 20-terminal LCCC package.

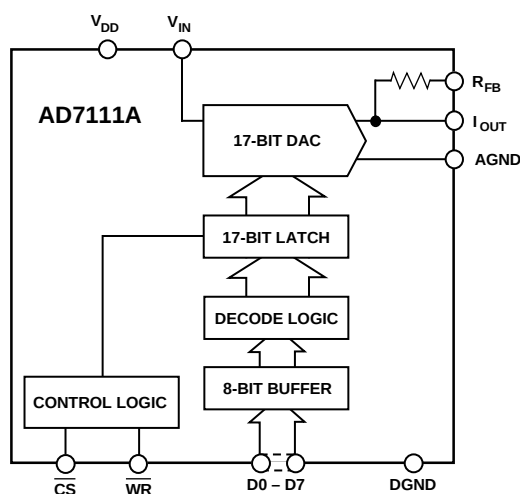
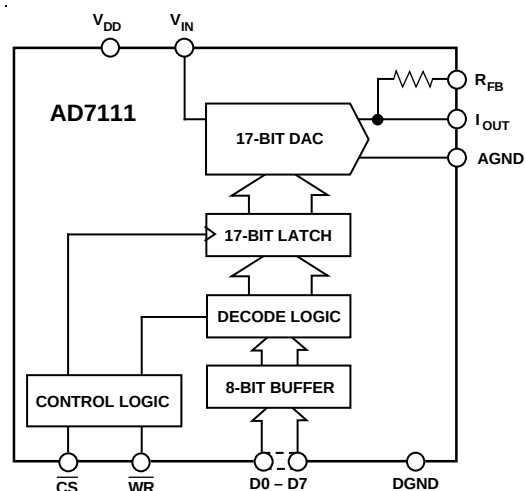
The degree of attenuation across the DAC is determined by an 8-bit word applied to the onboard decode logic. This 8-bit word is decoded into a 17-bit word which is then applied to a 17-bit R-2R ladder. The very fine step resolution, which is available over the entire dynamic range, is due to the use of this 17-bit DAC.

The AD7111/AD7111A are easily interfaced to a standard 8-bit MPU bus via an 8-bit data port and standard microprocessor control lines. The AD7111  $\overline{WR}$  input is edge triggered and requires a rising edge to load new data to the DAC. The AD7111A  $\overline{WR}$  is level triggered to allow transparent operation of the latches, if required. It should also be noted that the AD7111A is exactly pin and function-compatible with the AD7524, an industry standard 8-bit multiplying DAC. This allows an easy upgrading of existing AD7524 designs which would benefit both from the wider dynamic range and the finer step resolution offered by the AD7111A.

The AD7111/AD7111A are fabricated in Linear Compatible CMOS (LC<sup>2</sup>MOS), an advanced, mixed technology process that combines precision bipolar circuits with low power CMOS logic.

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### FUNCTIONAL BLOCK DIAGRAMS



### PRODUCT HIGHLIGHTS

1. Wide Dynamic Range: 0 dB to 88.5 dB attenuation range in 0.375 dB steps.
2. Small Package: The AD7111/AD7111A are available in 16-pin DIPs and SOIC packages.
3. Transparent Latch Operation: By tying the  $\overline{CS}$  and  $\overline{WR}$  inputs low, the DAC latches in the AD7111A can be made transparent.
4. Fast Microprocessor Interface: Data setup times of 25 ns and write pulse width of 57 ns make the AD7111A compatible with modern microprocessors.

### REV. 0

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# AD7111/AD7111A—SPECIFICATIONS

## AD7111—ELECTRICAL CHARACTERISTICS ( $V_{DD} = +5\text{ V}$ , $V_{IN} = -10\text{ V dc}$ , $I_{OUT} = \text{AGND} = \text{DGND} = 0\text{ V}$ output amplifier AD711 except where noted)

| Parameter                                                                                                        | AD7111L/C/U Grades              |                                   | AD7111K/B/T Grades              |                                   | Units                                                               | Conditions/Comments                                                                                                                                                       |
|------------------------------------------------------------------------------------------------------------------|---------------------------------|-----------------------------------|---------------------------------|-----------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                  | $T_A = +25^\circ\text{C}$       | $T_A = T_{MIN}, T_{MAX}$          | $T_A = +25^\circ\text{C}$       | $T_A = T_{MIN}, T_{MAX}$          |                                                                     |                                                                                                                                                                           |
| NOMINAL RESOLUTION                                                                                               | 0.375                           | 0.375                             | 0.375                           | 0.375                             | dB                                                                  |                                                                                                                                                                           |
| ACCURACY RELATIVE TO<br>0 dB ATTENUATION<br>0.375 dB Steps:<br>Accuracy $\leq \pm 0.17\text{ dB}$<br>Monotonic   | 0 to 36<br>0 to 54              | 0 to 36<br>0 to 54                | 0 to 30<br>0 to 48              | 0 to 30<br>0 to 48                | dB min<br>dB min                                                    | Guaranteed Attenuation Ranges<br>for Specified Step Sizes                                                                                                                 |
| 0.75 dB Steps:<br>Accuracy $\leq \pm 0.35\text{ dB}$<br>Monotonic                                                | 0 to 48<br>0 to 72              | 0 to 42<br>0 to 66                | 0 to 42<br>0 to 72              | 0 to 36<br>0 to 60                | dB min<br>dB min                                                    |                                                                                                                                                                           |
| 1.5 dB Steps:<br>Accuracy $\leq \pm 0.7\text{ dB}$<br>Monotonic                                                  | 0 to 54<br>Full Range           | 0 to 48<br>0 to 78                | 0 to 42<br>0 to 85.5            | 0 to 42<br>0 to 72                | dB min<br>dB min                                                    | Full Range Is from 0 dB<br>to 88.5 dB                                                                                                                                     |
| 3.0 dB Steps:<br>Accuracy $\leq \pm 1.4\text{ dB}$<br>Monotonic                                                  | 0 to 66<br>Full Range           | 0 to 54<br>Full Range             | 0 to 60<br>Full Range           | 0 to 48<br>Full Range             | dB min<br>dB min                                                    |                                                                                                                                                                           |
| 6.0 dB Steps:<br>Accuracy $\leq \pm 2.7\text{ dB}$<br>Monotonic                                                  | 0 to 72<br>Full Range           | 0 to 60<br>Full Range             | 0 to 60<br>Full Range           | 0 to 48<br>Full Range             | dB min<br>dB min                                                    |                                                                                                                                                                           |
| GAIN ERROR                                                                                                       | $\pm 0.1$                       | $\pm 0.15$                        | $\pm 0.15$                      | $\pm 0.20$                        | dB max                                                              |                                                                                                                                                                           |
| $V_{IN}$ INPUT RESISTANCE                                                                                        | 9/11/15                         | 9/11/15                           | 7/11/18                         | 7/11/18                           | k $\Omega$ min/typ/max                                              |                                                                                                                                                                           |
| $R_{FB}$ INPUT RESISTANCE                                                                                        | 9.3/11.5/15.7                   | 9.3/11.5/15.7                     | 7.3/11.5/18.8                   | 7.3/11.5/18.8                     | k $\Omega$ min/typ/max                                              |                                                                                                                                                                           |
| DIGITAL INPUTS<br>$V_{IH}$ (Input High Voltage)<br>$V_{IL}$ (Input Low Voltage)<br>Input Leakage Current         | 2.4<br>0.8<br>$\pm 1$           | 2.4<br>0.8<br>$\pm 10$            | 2.4<br>0.8<br>$\pm 1$           | 2.4<br>0.8<br>$\pm 10$            | V min<br>V max<br>$\mu\text{A}$ max                                 | Digital Inputs = $V_{DD}$                                                                                                                                                 |
| SWITCHING CHARACTERISTICS <sup>1</sup><br>$t_{CS}$<br>$t_{CH}$<br>$t_{WR}$<br>$t_{DS}$<br>$t_{DH}$<br>$t_{RFSH}$ | 0<br>0<br>350<br>175<br>10<br>3 | 0<br>0<br>500<br>250<br>10<br>4.5 | 0<br>0<br>350<br>175<br>10<br>3 | 0<br>0<br>500<br>250<br>10<br>4.5 | ns min<br>ns min<br>ns min<br>ns min<br>ns min<br>$\mu\text{s}$ min | Chip Select to Write Setup Time<br>Chip Select to Write Hold Time<br>Write Pulse Width<br>Data Valid to Write Setup Time<br>Data Valid to Write Hold Time<br>Refresh Time |
| POWER SUPPLY<br>$V_{DD}$<br>$I_{DD}$                                                                             | +5<br>1<br>500                  | +5<br>4<br>1000                   | +5<br>1<br>500                  | +5<br>4<br>1000                   | V<br>mA max<br>$\mu\text{A}$ max                                    | Digital Inputs = $V_{IL}$ or $V_{IH}$<br>Digital Inputs = 0 V or $V_{DD}$ ;<br>See Figure 6                                                                               |

### NOTE

<sup>1</sup>Sample tested at  $+25^\circ\text{C}$  to ensure compliance.

Specifications subject to change without notice.

## AC PERFORMANCE CHARACTERISTICS These characteristics are included for design guidance only and are not subject to test. $V_{DD} = +5\text{ V}$ , $V_{IN} = -10\text{ V dc}$ except where noted, $I_{OUT} = \text{AGND} = \text{DGND} = 0\text{ V}$ , output amplifier AD711 except where noted.

| Parameter                                              | AD7111L/C/U Grades        |                          | AD7111K/B/T Grades        |                          | Units                      | Conditions/Comments                                                                                                                                                                                                                                                                 |
|--------------------------------------------------------|---------------------------|--------------------------|---------------------------|--------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                        | $T_A = +25^\circ\text{C}$ | $T_A = T_{MIN}, T_{MAX}$ | $T_A = +25^\circ\text{C}$ | $T_A = T_{MIN}, T_{MAX}$ |                            |                                                                                                                                                                                                                                                                                     |
| DC Supply Rejection, $\Delta\text{Gain}/\Delta V_{DD}$ | 0.001                     | 0.005                    | 0.001                     | 0.005                    | dB per % max               | $\Delta V_{DD} = \pm 10\%$ , Input Code = 00000000<br>Full-Scale Change Measured from<br>$\overline{\text{WR}}$ Going High, $\overline{\text{CS}} = 0\text{ V}$<br>Measured with AD843 as Output<br>Amplifier for Code Transition<br>10000000 to 00000000<br>C1 of Figure 1 is 0 pF |
| Propagation Delay                                      | 3.0                       | 4.5                      | 3.0                       | 4.5                      | $\mu\text{s}$ max          |                                                                                                                                                                                                                                                                                     |
| Digital-to-Analog Glitch Impulse                       | 100                       |                          | 100                       |                          | nV secs typ                |                                                                                                                                                                                                                                                                                     |
| Output Capacitance, Pin 1                              | 185                       | 185                      | 185                       | 185                      | pF max                     | $V_{IN} = 6\text{ V rms}$ at 1 kHz<br>Includes AD711 Amplifier Noise                                                                                                                                                                                                                |
| Input Capacitance, Pin 15 and Pin 16                   | 7                         | 7                        | 7                         | 7                        | pF max                     |                                                                                                                                                                                                                                                                                     |
| Feedthrough at 1 kHz                                   | -94                       | -72                      | -94                       | -68                      | dB max                     |                                                                                                                                                                                                                                                                                     |
| Total Harmonic Distortion                              | -91                       | -91                      | -91                       | -91                      | dB typ                     |                                                                                                                                                                                                                                                                                     |
| Output Noise Voltage Density                           | 70                        | 70                       | 70                        | 70                       | nV/ $\sqrt{\text{Hz}}$ max |                                                                                                                                                                                                                                                                                     |
| Digital Input Capacitance                              | 7                         | 7                        | 7                         | 7                        | pF max                     |                                                                                                                                                                                                                                                                                     |

Specifications subject to change without notice.

# AD7111A—ELECTRICAL CHARACTERISTICS

( $V_{DD} = +5\text{ V}$ ,  $V_{IN} = -10\text{ V dc}$ ,  $I_{OUT} = \text{AGND} = \text{DGND} = 0\text{ V}$  output amplifier AD711 except where noted)

| Parameter                                                                                                      | AD7111AC Grade            |                                        | AD7111AB Grade            |                                        | Units                                          | Conditions/Comments                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------|---------------------------|----------------------------------------|---------------------------|----------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                | $T_A = +25^\circ\text{C}$ | $T_A = T_{\text{MIN}}, T_{\text{MAX}}$ | $T_A = +25^\circ\text{C}$ | $T_A = T_{\text{MIN}}, T_{\text{MAX}}$ |                                                |                                                                                                                                                           |
| NOMINAL RESOLUTION                                                                                             | 0.375                     | 0.375                                  | 0.375                     | 0.375                                  | dB                                             |                                                                                                                                                           |
| ACCURACY RELATIVE TO<br>0 dB ATTENUATION<br>0.375 dB Steps:<br>Accuracy $\leq \pm 0.17\text{ dB}$<br>Monotonic | 0 to 36<br>0 to 54        | 0 to 36<br>0 to 54                     | 0 to 30<br>0 to 48        | 0 to 30<br>0 to 48                     | dB min<br>dB min                               | Guaranteed Attenuation Ranges<br>for Specified Step Sizes                                                                                                 |
| 0.75 dB Steps:<br>Accuracy $\leq \pm 0.35\text{ dB}$<br>Monotonic                                              | 0 to 48<br>0 to 72        | 0 to 42<br>0 to 66                     | 0 to 42<br>0 to 72        | 0 to 36<br>0 to 60                     | dB min<br>dB min                               |                                                                                                                                                           |
| 1.5 dB Steps:<br>Accuracy $\leq \pm 0.7\text{ dB}$<br>Monotonic                                                | 0 to 54<br>Full Range     | 0 to 48<br>0 to 78                     | 0 to 48<br>0 to 85.5      | 0 to 42<br>0 to 72                     | dB min<br>dB min                               | Full Range Is from 0 dB<br>to 88.5 dB                                                                                                                     |
| 3.0 dB Steps:<br>Accuracy $\leq \pm 1.4\text{ dB}$<br>Monotonic                                                | 0 to 66<br>Full Range     | 0 to 54<br>Full Range                  | 0 to 60<br>Full Range     | 0 to 48<br>Full Range                  | dB min<br>dB min                               |                                                                                                                                                           |
| 6.0 dB Steps:<br>Accuracy $\leq \pm 2.7\text{ dB}$<br>Monotonic                                                | 0 to 72<br>Full Range     | 0 to 60<br>Full Range                  | 0 to 60<br>Full Range     | 0 to 48<br>Full Range                  | dB min<br>dB min                               |                                                                                                                                                           |
| GAIN ERROR                                                                                                     | $\pm 0.1$                 | $\pm 0.15$                             | $\pm 0.15$                | $\pm 0.20$                             | dB max                                         |                                                                                                                                                           |
| $V_{IN}$ INPUT RESISTANCE                                                                                      | 9/11/15                   | 9/11/15                                | 7/11/18                   | 7/11/18                                | k $\Omega$ min/typ/max                         |                                                                                                                                                           |
| $R_{FB}$ INPUT RESISTANCE                                                                                      | 9.3/11.5/15.7             | 9.3/11.5/15.7                          | 7.3/11.5/18.8             | 7.3/11.5/18.8                          | k $\Omega$ min/typ/max                         |                                                                                                                                                           |
| DIGITAL INPUTS<br>$V_{IH}$ (Input High Voltage)<br>$V_{IL}$ (Input High Voltage)<br>Input Leakage Current      | 2.4<br>0.8<br>$\pm 1$     | 2.4<br>0.8<br>$\pm 10$                 | 2.4<br>0.8<br>$\pm 1$     | 2.4<br>0.8<br>$\pm 10$                 | V min<br>V max<br>$\mu\text{A}$ max            | Digital Inputs = $V_{DD}$                                                                                                                                 |
| SWITCHING CHARACTERISTICS <sup>1</sup><br>$t_{CS}$<br>$t_{CH}$<br>$t_{WR}$<br>$t_{DS}$<br>$t_{DH}$             | 0<br>0<br>57<br>25<br>10  | 0<br>0<br>57<br>25<br>10               | 0<br>0<br>57<br>25<br>10  | 0<br>0<br>57<br>25<br>10               | ns min<br>ns min<br>ns min<br>ns min<br>ns min | Chip Select to Write Setup Time<br>Chip Select to Write Hold Time<br>Write Pulse Width<br>Data Valid to Write Setup Time<br>Data Valid to Write Hold Time |
| POWER SUPPLY<br>$V_{DD}$<br>$I_{DD}$                                                                           | +5<br>1<br>1              | +5<br>2<br>1                           | +5<br>1<br>1              | +5<br>2<br>1                           | V<br>mA max<br>mA max                          | Digital Inputs = $V_{IL}$ or $V_{IH}$<br>$\overline{CS} = \overline{WR} = 0\text{ V}$<br>Digital Inputs = 0 V or $V_{DD}$ ;<br>See Figure 6               |

## NOTE

<sup>1</sup>Sample tested at  $+25^\circ\text{C}$  to ensure compliance.

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## AC PERFORMANCE CHARACTERISTICS

These characteristics are included for design guidance only and are not subject to test.  $V_{DD} = +5\text{ V}$ ,  $V_{IN} = -10\text{ V dc}$  except where noted,  $I_{OUT} = \text{AGND} = \text{DGND} = 0\text{ V}$ , output amplifier AD711 except where noted.

| Parameter                                              | AD7111AC Grade            |                                        | AD7111AB Grade            |                                        | Units                      | Conditions/Comments                                                                                                                               |
|--------------------------------------------------------|---------------------------|----------------------------------------|---------------------------|----------------------------------------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                        | $T_A = +25^\circ\text{C}$ | $T_A = T_{\text{MIN}}, T_{\text{MAX}}$ | $T_A = +25^\circ\text{C}$ | $T_A = T_{\text{MIN}}, T_{\text{MAX}}$ |                            |                                                                                                                                                   |
| DC Supply Rejection, $\Delta\text{Gain}/\Delta V_{DD}$ | 0.001                     | 0.005                                  | 0.001                     | 0.005                                  | dB per % max               | $\Delta V_{DD} = \pm 10\%$ , Input Code = 00000000<br>Full-Scale Change Measured from<br>$\overline{WR}$ Going High, $\overline{CS} = 0\text{ V}$ |
| Propagation Delay                                      | 1                         | 1.5                                    | 1                         | 1.5                                    | $\mu\text{s}$ max          |                                                                                                                                                   |
| Digital-to-Analog Glitch Impulse                       | 10                        | 20                                     | 10                        | 20                                     | nV secs typ                | Measured with AD843 as Output<br>Amplifier for Code Transition<br>10000000 to 00000000<br>C1 of Figure 1 is 0 pF                                  |
| Output Capacitance, Pin 1                              | 50                        | 50                                     | 50                        | 50                                     | pF max                     | $V_{IN} = 6\text{ V rms}$ at 1 kHz<br>Includes AD711 Amplifier Noise                                                                              |
| Input Capacitance, Pin 15 and Pin 16                   | 7                         | 7                                      | 7                         | 7                                      | pF max                     |                                                                                                                                                   |
| Feedthrough at 1 kHz                                   | -94                       | -90                                    | -92                       | -90                                    | dB max                     |                                                                                                                                                   |
| Total Harmonic Distortion                              | -91                       | -91                                    | -91                       | -91                                    | dB typ                     |                                                                                                                                                   |
| Output Noise Voltage Density                           | 70                        | 70                                     | 70                        | 70                                     | nV/ $\sqrt{\text{Hz}}$ max |                                                                                                                                                   |
| Digital Input Capacitance                              | 7                         | 7                                      | 7                         | 7                                      | pF max                     |                                                                                                                                                   |

Specifications subject to change without notice.

# AD7111/AD7111A

## ABSOLUTE MAXIMUM RATINGS\*

(T<sub>A</sub> = +25°C unless otherwise noted)

|                                       |                                   |
|---------------------------------------|-----------------------------------|
| V <sub>DD</sub> (to DGND)             | +7 V                              |
| V <sub>IN</sub> (to AGND)             | ±35 V                             |
| Digital Input Voltage to DGND         | −0.3 V to V <sub>DD</sub> + 0.3 V |
| I <sub>OUT</sub> to AGND              | −0.3 V to V <sub>DD</sub>         |
| V <sub>RFB</sub> to AGND              | ±35 V                             |
| AGND to DGND                          | 0 to V <sub>DD</sub>              |
| DGND to AGND                          | 0 to V <sub>DD</sub>              |
| Power Dissipation, DIP                | 1 W                               |
| θ <sub>JA</sub> , Thermal Impedance   | 117°C/W                           |
| Lead Temperature (Soldering, 10 secs) | +300°C                            |
| Power Dissipation, SOIC               | 1 W                               |
| θ <sub>JA</sub> , Thermal Impedance   | 75°C/W                            |
| Lead Temperature (Soldering)          |                                   |
| Vapor Phase (60 secs)                 | 215°C                             |
| Infrared (15 secs)                    | 220°C                             |

|                                       |                 |
|---------------------------------------|-----------------|
| Power Dissipation, LCCC               | 1 W             |
| θ <sub>JA</sub> , Thermal Impedance   | 76°C/W          |
| Lead Temperature (Soldering, 10 secs) | +300°C          |
| Operating Temperature Range           |                 |
| Commercial (K, L Versions)            | 0°C to +70°C    |
| Industrial (B, C Versions)            | −40°C to +85°C  |
| Extended (T, U Versions)              | −55°C to +125°C |
| Storage Temperature Range             | −65°C to +150°C |

\*Stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only, and functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD7111/AD7111A features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.



## ORDERING GUIDES

### AD7111A ORDERING GUIDE

| Model     | Temperature Range | Specified Accuracy Range | Package Option <sup>1</sup> |
|-----------|-------------------|--------------------------|-----------------------------|
| AD7111ABN | −40°C to +85°C    | 0 dB to 60 dB            | N-16                        |
| AD7111ACN | −40°C to +85°C    | 0 dB to 72 dB            | N-16                        |
| AD7111ABR | −40°C to +85°C    | 0 dB to 60 dB            | R-16                        |
| AD7111ACR | −40°C to +85°C    | 0 dB to 72 dB            | R-16                        |

NOTE

<sup>1</sup>N = Plastic DIP; R = SOIC.

## TERMINOLOGY

**RESOLUTION:** Nominal change in attenuation when moving between two adjacent codes.

**MONOTONICITY:** The device is monotonic if the analog output decreases (or remains constant) as the digital code increases.

**FEEDTHROUGH ERROR:** That portion of the input signal which reaches the output when all digital inputs are high. See section on Applications.

**OUTPUT LEAKAGE CURRENT:** Current which appears on the I<sub>OUT</sub> terminal with all digital inputs high.

**TOTAL HARMONIC DISTORTION:** A measure of the harmonics introduced by the circuit when a pure sinusoid is applied to the input. It is expressed as the harmonic energy divided by the fundamental energy at the output.

### AD7111 ORDERING GUIDE

| Model <sup>1</sup> | Temperature Range | Specified Accuracy Range | Package Option <sup>2</sup> |
|--------------------|-------------------|--------------------------|-----------------------------|
| AD7111KN           | 0°C to +70°C      | 0 dB to 60 dB            | N-16                        |
| AD7111BQ           | −40°C to +85°C    | 0 dB to 60 dB            | Q-16                        |
| AD7111LN           | 0°C to +70°C      | 0 dB to 72 dB            | N-16                        |
| AD7111CQ           | −40°C to +85°C    | 0 dB to 72 dB            | Q-16                        |
| AD7111UQ/883B      | −55°C to +125°C   | 0 dB to 72 dB            | Q-16                        |
| AD7111TE/883B      | −55°C to +125°C   | 0 dB to 60 dB            | E-20A                       |

NOTES

<sup>1</sup>To order MIL-STD-883B, Class B processed parts, add /883B to part number. Contact local sales office for military data sheet and availability.

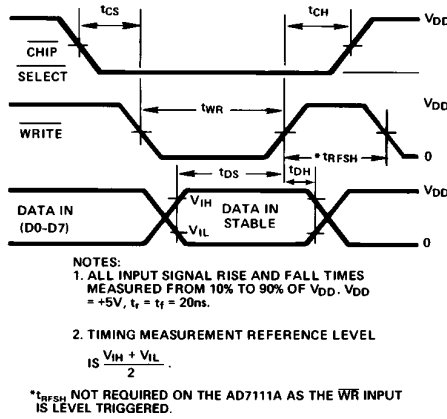
<sup>2</sup>N = Plastic DIP; Q = Cerdip; E = LCCC; R = SOIC.

**ACCURACY:** The difference (measured in dB) between the ideal transfer function as listed in Table I and the actual transfer function as measured with the device.

**OUTPUT CAPACITANCE:** Capacitance from I<sub>OUT</sub> to ground.

**DIGITAL-TO-ANALOG GLITCH IMPULSE:** The amount of charge injected from the digital inputs to the analog output when the inputs change state. This is normally specified as the area of the glitch in either pA-secs or nV-secs depending upon whether the glitch is measured as a current or voltage signal. Glitch impulse is measured with V<sub>IN</sub> = AGND.

**PROPAGATION DELAY:** This is a measure of the internal delays of the circuit and is defined as the time from a digital input change to the analog output current reaching 90% of its final value.



Write Cycle Timing Diagram

## CIRCUIT DESCRIPTION

### GENERAL CIRCUIT DESCRIPTION

The AD7111/AD7111A consists of a 17-bit R-2R CMOS multiplying D/A converter with extensive digital logic. The logic translates the 8-bit binary input into a 17-bit word which is used to drive the D/A converter. Input data on the D7-D0 bus is loaded into the input data latches using  $\overline{CS}$  and  $\overline{WR}$  control signals. When using the AD7111, the rising edge of  $\overline{WR}$  latches the input data and initiates the internal data transfer to the decoder. A minimum time  $t_{RFSH}$ , the refresh time, is required for the data to propagate through the decoder before a new data write is attempted.

In contrast, the AD7111A  $\overline{WR}$  input is level triggered to allow transparent operation of the latches if required.

The transfer function for the circuit of Figure 1 is given by:

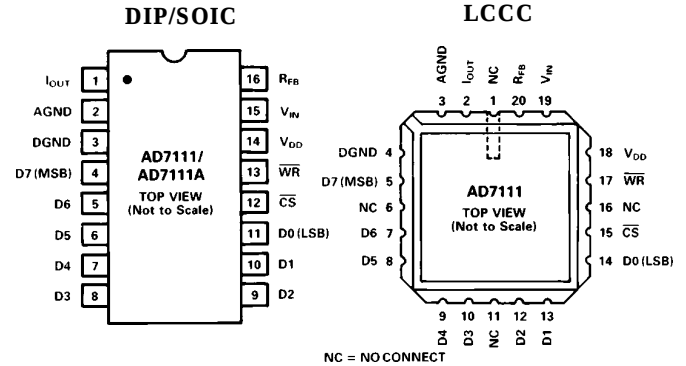
$$V_O = -V_{IN} 10 \exp - \frac{0.375 N}{20}$$

$$\text{or } \left| \frac{V_O}{V_{IN}} \right| \text{ dB} = -0.375 N$$

Table I. Ideal Attenuation in dB vs. Input Code

| D3-D0 | 0000 | 0001   | 0010  | 0011   | 0100 | 0101   | 0110  | 0111   | 1000 | 1001   | 1010  | 1011   | 1100 | 1101   | 1110  | 1111   |
|-------|------|--------|-------|--------|------|--------|-------|--------|------|--------|-------|--------|------|--------|-------|--------|
| 0000  | 0.0  | 0.375  | 0.75  | 1.125  | 1.5  | 1.875  | 2.25  | 2.625  | 3.0  | 3.375  | 3.75  | 4.125  | 4.5  | 4.875  | 5.25  | 5.625  |
| 0001  | 6.0  | 6.375  | 6.75  | 7.125  | 7.5  | 7.875  | 8.25  | 8.625  | 9.0  | 9.375  | 9.75  | 10.125 | 10.5 | 10.875 | 11.25 | 11.625 |
| 0010  | 12.0 | 12.375 | 12.75 | 13.125 | 13.5 | 13.875 | 14.25 | 14.625 | 15.0 | 15.375 | 15.75 | 16.125 | 16.5 | 16.875 | 17.25 | 17.625 |
| 0011  | 18.0 | 18.375 | 18.75 | 19.125 | 19.5 | 19.875 | 20.25 | 20.625 | 21.0 | 21.375 | 21.75 | 22.125 | 22.5 | 22.875 | 23.25 | 23.625 |
| 0100  | 24.0 | 24.375 | 24.75 | 25.125 | 25.5 | 25.875 | 26.25 | 26.625 | 27.0 | 27.375 | 27.75 | 28.125 | 28.5 | 28.875 | 29.25 | 29.625 |
| 0101  | 30.0 | 30.375 | 30.75 | 31.125 | 31.5 | 31.875 | 32.25 | 32.625 | 33.0 | 33.375 | 33.75 | 34.125 | 34.5 | 34.875 | 35.25 | 35.625 |
| 0110  | 36.0 | 36.375 | 36.75 | 37.125 | 37.5 | 37.875 | 38.25 | 38.625 | 39.0 | 39.375 | 39.75 | 40.125 | 40.5 | 40.875 | 41.25 | 41.625 |
| 0111  | 42.0 | 42.375 | 42.75 | 43.125 | 43.5 | 43.875 | 44.25 | 44.625 | 45.0 | 45.375 | 45.75 | 46.125 | 46.5 | 46.875 | 47.25 | 47.625 |
| 1000  | 48.0 | 48.375 | 48.75 | 49.125 | 49.5 | 49.875 | 50.25 | 50.625 | 51.0 | 51.375 | 51.75 | 52.125 | 52.5 | 52.875 | 53.25 | 53.625 |
| 1001  | 54.0 | 54.375 | 54.75 | 55.125 | 55.5 | 55.875 | 56.25 | 56.625 | 57.0 | 57.375 | 57.75 | 58.125 | 58.5 | 58.875 | 59.25 | 59.625 |
| 1010  | 60.0 | 60.375 | 60.75 | 61.125 | 61.5 | 61.875 | 62.25 | 62.625 | 63.0 | 63.375 | 63.75 | 64.125 | 64.5 | 64.875 | 65.25 | 65.625 |
| 1011  | 66.0 | 66.375 | 66.75 | 67.125 | 67.5 | 67.875 | 68.25 | 68.625 | 69.0 | 69.375 | 69.75 | 70.125 | 70.5 | 70.875 | 71.25 | 71.625 |
| 1100  | 72.0 | 72.375 | 72.75 | 73.125 | 73.5 | 73.875 | 74.25 | 74.625 | 75.0 | 75.375 | 75.75 | 76.125 | 76.5 | 76.875 | 77.25 | 77.625 |
| 1101  | 78.0 | 78.375 | 78.75 | 79.125 | 79.5 | 79.875 | 80.25 | 80.625 | 81.0 | 81.375 | 81.75 | 82.125 | 82.5 | 82.875 | 83.25 | 83.625 |
| 1110  | 84.0 | 84.375 | 84.75 | 85.125 | 85.5 | 85.875 | 86.25 | 86.625 | 87.0 | 87.375 | 87.75 | 88.125 | 88.5 | 88.875 | 89.25 | 89.625 |
| 1111  | MUTE | MUTE   | MUTE  | MUTE   | MUTE | MUTE   | MUTE  | MUTE   | MUTE | MUTE   | MUTE  | MUTE   | MUTE | MUTE   | MUTE  | MUTE   |

## PIN CONFIGURATIONS



where 0.375 is the step size (resolution) in dB and N is the input code in decimal for values 0 to 239. For  $240 \leq N \leq 255$  the output is zero. Table I gives the output attenuation relative to 0 dB for all possible input codes.

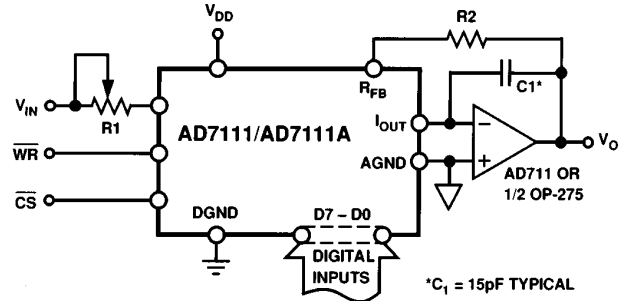


Figure 1. Typical Circuit Configuration

The graphs on the last page give a pictorial representation of the specified accuracy and monotonic ranges for all grades of the AD7111/AD7111A. High attenuation levels are specified with less accuracy than low attenuation levels. The range of monotonic behavior depends upon the attenuation step size used.

# AD7111/AD7111A

For example, the AD7111L is guaranteed monotonic in 0.375 dB steps from 0 dB to -54 dB inclusive and in 0.75 dB steps from 0 dB to -72 dB inclusive. To achieve monotonic operation over the entire 88.5 dB range it is necessary to select input codes so that the attenuation step size at any point is consistent with the step size guaranteed for monotonic operation at that point.

## EQUIVALENT CIRCUIT ANALYSIS

Figure 2 shows a simplified circuit of the D/A converter section of the AD7111/AD7111A, and Figure 3 gives an approximate equivalent circuit.

The current source  $I_{LEAKAGE}$  is composed of surface and junction leakages. The resistor  $R_0$  as shown in Figure 3 is the equivalent output resistance of the device which varies with input code (excluding all 0s code) from  $0.8R$  to  $2R$ .  $R$  is typically 12 k $\Omega$ .  $C_{OUT}$  is the capacitance due to the N channel switches and varies from about 20 pF to 50 pF depending upon the digital input. For further information on CMOS multiplying D/A converters, refer to "CMOS DAC Application Guide" which is available from Analog Devices, Publication Number G872b-8-1/89.

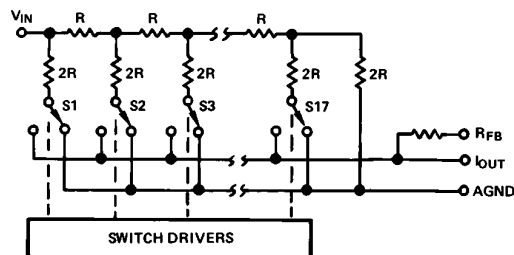


Figure 2. Simplified D/A Circuit of AD7111/AD7111A

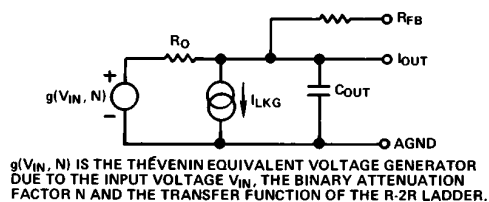


Figure 3. Equivalent Analog Output Circuit of AD7111/AD7111A

## DYNAMIC PERFORMANCE

The dynamic performance of the AD7111/AD7111A will depend upon the gain and phase characteristics of the output amplifier, together with the optimum choice of PC board layout and decoupling components. Circuit layout is most important if the optimum performance of the AD7111/AD7111A is to be achieved. Most application problems stem from either poor layout, grounding errors, or inappropriate choice of amplifier.

It is recommended that when using the AD7111/AD7111A with a high speed amplifier, a capacitor ( $C_1$ ) be connected in the feedback path as shown in Figure 1. This capacitor, which should be between 10 pF and 30 pF, compensates for the phase lag introduced by the output capacitance of the D/A converter. Figures 4 and 5 show the performance of the AD7111/AD7111A using the AD711, a high speed, low cost BiFET amplifier, and the OP275, a dual, bipolar/JFET, audio amplifier. The performance without  $C_1$  is shown in the middle trace and the response with  $C_1$  in circuit shown in the bottom trace.

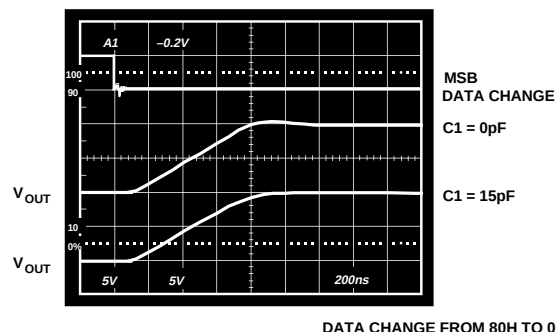


Figure 4. Response of AD7111/AD7111A with AD711

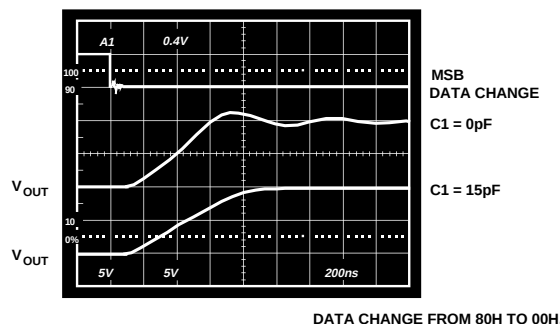


Figure 5. Response of AD7111/AD7111A with 1/2 OP275

In conventional CMOS D/A converter design, parasitic capacitance in N-channel D/A converter switches can give rise to glitches on the D/A converter output. These glitches result from digital feedthrough. The AD7111/AD7111A has been designed to minimize these glitches as much as possible.

For operation beyond 250 kHz, capacitor  $C_1$  may be reduced in value. This gives an increase in bandwidth at the expense of a poorer transient response as shown in Figures 5 and 11. In circuits where  $C_1$  is not included, the high frequency roll-off point is primarily determined by the characteristics of the output amplifier and not the AD7111/AD7111A.

Feedthrough and absolute accuracy are sensitive to output leakage current effects. For this reason it is recommended that the operating temperature of the AD7111/AD7111A be kept as close to 25°C as is practically possible, particularly where the device's performance at high attenuation levels is important. A typical plot of leakage current vs. temperature is shown in Figure 10. Some solder fluxes and cleaning materials can form slightly conductive films which cause leakage effects between analog input and output. The user is cautioned to ensure that the manufacturing process for circuits using the AD7111/AD7111A does not allow such films to form. Otherwise the feedthrough, accuracy and maximum usable range will be affected.

## STATIC ACCURACY PERFORMANCE

The D/A converter section of the AD7111/AD7111A consists of a 17-bit R-2R type converter. To obtain optimum static performance at this level of resolution it is necessary to pay great attention to amplifier selection, circuit grounding, etc.

Amplifier input has current results in a dc offset at the output of the amplifier due to the current flowing through the feedback resistor  $R_{FB}$ . It is recommended that an amplifier with an input bias current of less than 10 nA be used (e.g., AD711) to minimize this offset.

Another error arises from the output amplifier's input offset voltage. The amplifier is operated with a fixed feedback resistance, but the equivalent source impedance (the AD7111/AD7111A output impedance) varies as a function of attenuation level. This has the effect of varying the “noise” gain of the amplifier, thus creating a varying error due to amplifier offset voltage. It is recommended that an amplifier with less than 50  $\mu\text{V}$  of input offset be used (such as the AD OP07 in dc applications). Amplifiers with higher offset voltage may cause audible “thumps” in ac applications due to dc output changes.

The AD7111/AD7111A accuracy is specified and tested using only the internal feedback resistor. Any gain error (i.e., mismatch of  $R_{FB}$  to the R-2R ladder) that may exist in the

AD7111/AD7111A D/A converter circuit results in a constant attenuation error over the whole range. The AD7111/AD7111A accuracy is specified relative to 0 dB attenuation, hence “Gain” trim resistors— $R_1$  and  $R_2$  in Figure 1—can be used to adjust  $V_{OUT} = V_{IN}$  precisely (i.e., 0 dB attenuation) with input code 00000000. The accuracy and monotonic range specifications of the AD7111/AD7111A are not affected in any way by this gain trim procedure. For the AD7111/AD7111A L/C/U grades, suitable values for  $R_1$  and  $R_2$  of Figure 1 are  $R_1 = 500\ \Omega$ ,  $R_2 = 180\ \Omega$ ; for the K/B/T grades, suitable values are  $R_1 = 1000\ \Omega$ ,  $R_2 = 270\ \Omega$ . For additional information on gain error the reader is referred to the “CMOS DAC Application Guide,” available from Analog Devices, Inc., Publication Number G872b-8-1/89.

## Typical Performance Characteristics

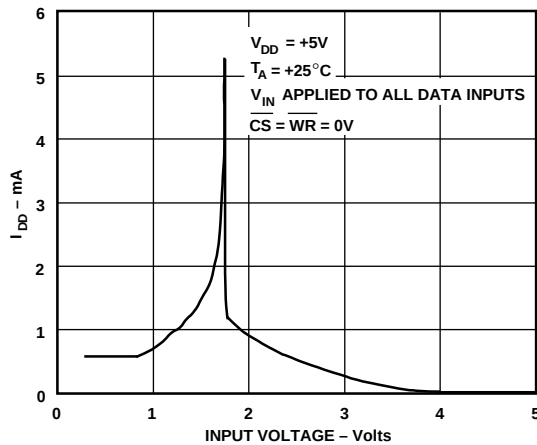


Figure 6. Typical Supply Current vs. Logic Input Level

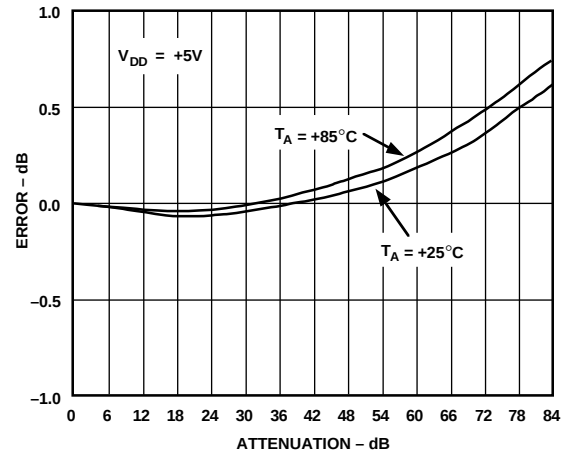


Figure 8. Typical Attenuation Error for 3 dB Steps vs. Temperature

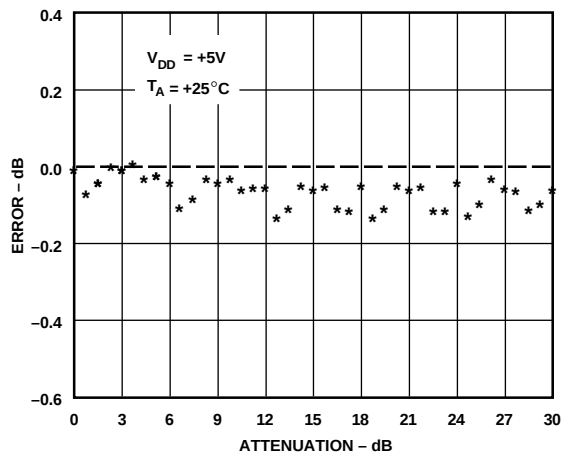


Figure 7. Typical Attenuation Error for 0.75 dB Steps

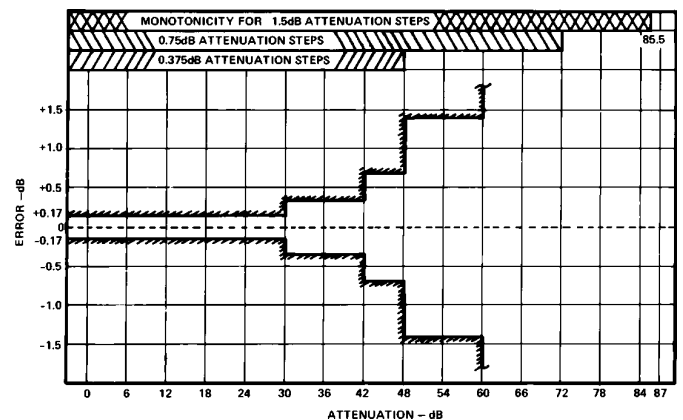


Figure 9. Accuracy Specification for K/B/T Grade Devices at  $T_A = +25^\circ\text{C}$

# AD7111/AD7111A—Typical Performance Characteristics

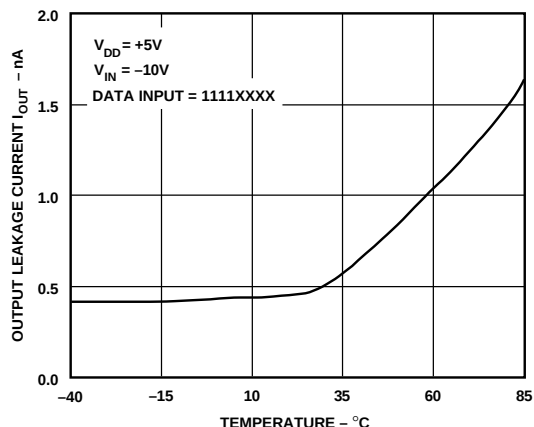


Figure 10. Output Leakage Current vs. Temperature

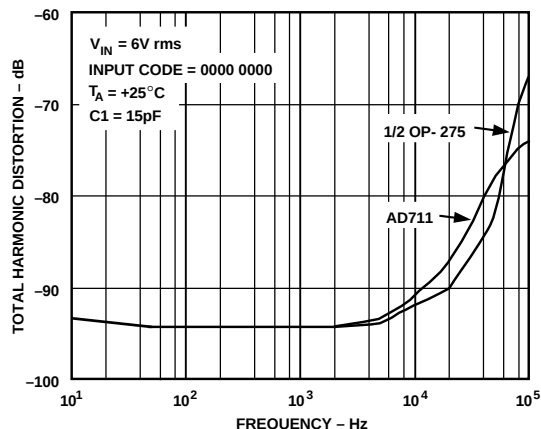


Figure 12. Distortion vs. Frequency

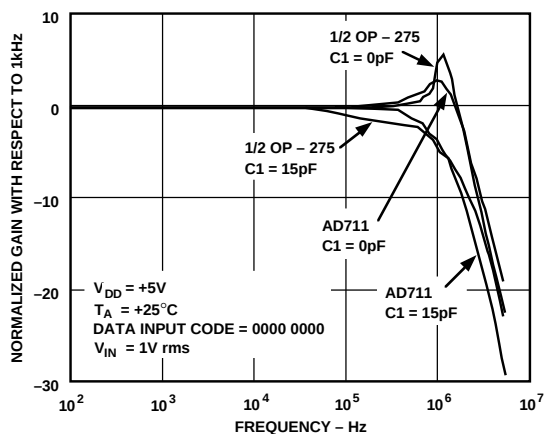


Figure 11. Frequency Response with 1/2 OP275 and AD711 Amplifiers

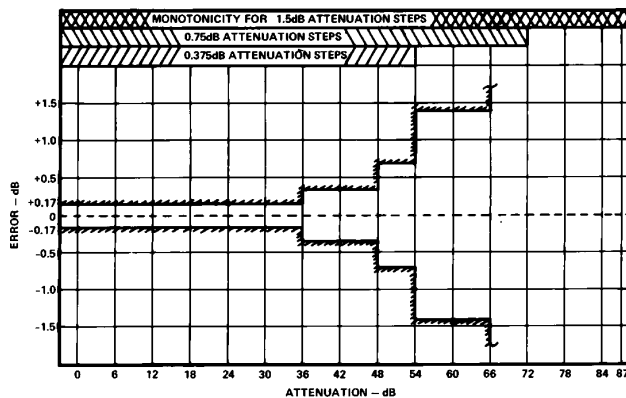
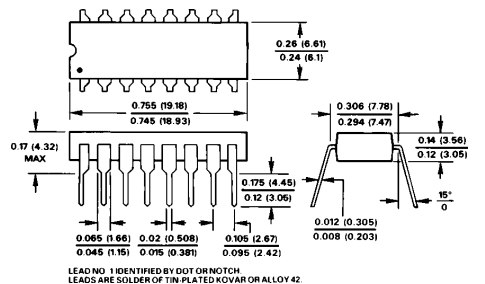


Figure 13. Accuracy Specification for L/C/U Grade Devices at  $T_A = +25^\circ\text{C}$

## OUTLINE DIMENSIONS

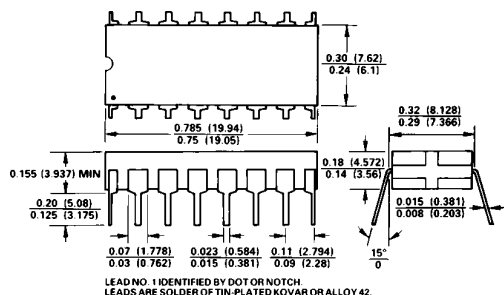
Dimensions shown in inches and (mm).

### Plastic DIP (N-16)



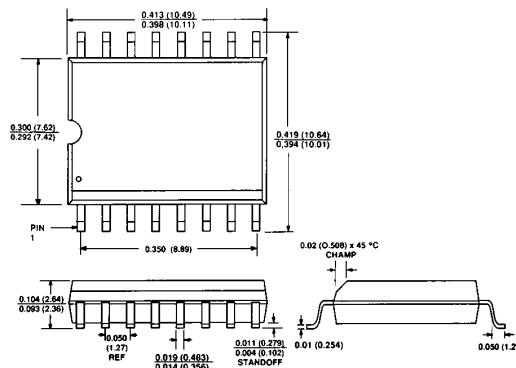
LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH.  
LEADS ARE SOLDER OF TIN-PLATED KOVAR OR ALLOY 42.

### Cerdip (Q-16)

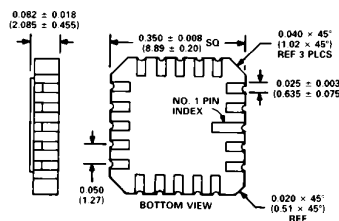


LEAD NO. 1 IDENTIFIED BY DOT OR NOTCH.  
LEADS ARE SOLDER OF TIN-PLATED KOVAR OR ALLOY 42.

### SOIC (R-16)



### LCCC (E-20A)



## Package/Price Information

Monolithic multiplying D/A converters featuring wide dynamic range

| Model          | Status      | Package Description         | Pin Count | Temperature Range | Price* (100-499) |
|----------------|-------------|-----------------------------|-----------|-------------------|------------------|
| AD7111ABCHIPS  | PRODUCTION  | NO CONVERSION DATA FROM COS | -         | COMMERCIAL        | \$5.27           |
| AD7111ABN      | PRODUCTION  | PLASTIC/EPOXY DIP           | 16        | COMMERCIAL        | -                |
| AD7111ABR      | PRODUCTION  | SOIC WIDE .300" -2mm THICK  | 16        | COMMERCIAL        | -                |
| AD7111ABR-REEL | PRODUCTION  | SOIC WIDE .300" -2mm THICK  | 16        | COMMERCIAL        | -                |
| AD7111ACN      | PRODUCTION  | PLASTIC/EPOXY DIP           | 16        | COMMERCIAL        | -                |
| AD7111ACR      | PRODUCTION  | SOIC WIDE .300" -2mm THICK  | 16        | COMMERCIAL        | \$9.38           |
| AD7111ACR-REEL | PRODUCTION  | SOIC WIDE .300" -2mm THICK  | 16        | COMMERCIAL        | -                |
| AD7111BCHIPS   | PRODUCTION  | CHIPS/DIE SALES             | 16        | INDUSTRIAL        | \$20.33          |
| AD7111BQ       | PRODUCTION  | CERDIP GLASS SEAL           | 16        | INDUSTRIAL        | -                |
| AD7111CQ       | OBSOLETE    | CERDIP GLASS SEAL           | 16        | INDUSTRIAL        | -                |
| AD7111KN       | PRODUCTION  | PLASTIC/EPOXY DIP           | 16        | COMMERCIAL        | \$22.36          |
| AD7111LN       | PRODUCTION  | PLASTIC/EPOXY DIP           | 16        | COMMERCIAL        | \$29.36          |
| AD7111UQ       | PRE-RELEASE | CERDIP GLASS SEAL           | 16        | MILITARY          | -                |
| AD7111UQ/883B  | PRODUCTION  | CERDIP GLASS SEAL           | 16        | MILITARY          | \$143.71         |

\* This price is provided for budgetary purposes as recommended list price in U.S. Dollars per unit in the stated volume. Pricing displayed for Evaluation Boards and Kits is based on 1-piece pricing. View [Pricing and Availability](#) for further information.

## AD7111

Description

Datasheets

Related Information

Package/Price Info

Purchase

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| AD7111ACR-REEL | PRODUCTION  | SOIC WIDE .300" -2mm THICK  | 16        | COMMERCIAL        | -                |
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| AD7111CQ       | OBSOLETE    | CERDIP GLASS SEAL           | 16        | INDUSTRIAL        | -                |
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