# Dual, Low Noise, Single-Supply Variable Gain Amplifier

# AD605

## FEATURES

**2 independent linear-in-dB channels**
**Input noise at maximum gain: 1.8 nV/√Hz, 2.7 pA/√Hz**
**Bandwidth: 40 MHz (−3 dB)**
**Differential input**
**Absolute gain range programmable**
**−14 dB to +34 dB (FBK shorted to OUT) through**
**0 dB to 48 dB (FBK open)**
**Variable gain scaling: 20 dB/V through 40 dB/V**
**Stable gain with temperature and supply variations**
**Single-ended unipolar gain control**
**Output common mode independently set**
**Power shutdown at lower end of gain control**
**Single 5 V supply**
**Low power: 90 mW/channel**
**Drives ADCs directly**

## FUNCTIONAL BLOCK DIAGRAM

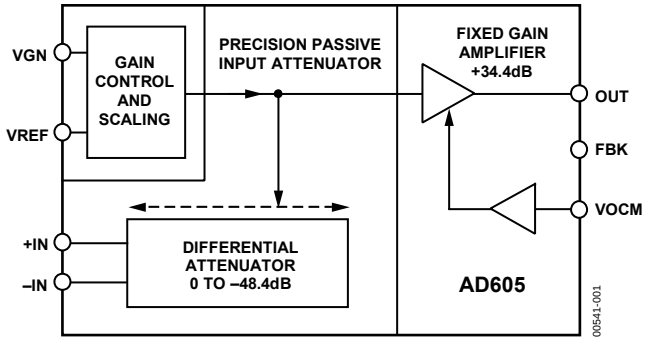



*Figure 1.*

## APPLICATIONS

**Ultrasound and sonar time-gain controls**
**High performance AGC systems**
**Signal measurement**

## GENERAL DESCRIPTION

The AD605 is a low noise, accurate, dual-channel, linear-in-dB variable gain amplifier (VGA), optimized for any application requiring high performance, wide bandwidth variable gain control. Operating from a single 5 V supply, the AD605 provides differential inputs and unipolar gain control for ease of use. Added flexibility is achieved with a user-determined gain range and an external reference input that provide user-determined gain scaling (dB/V).

The high performance linear-in-dB response of the AD605 is achieved with the differential input, single-supply, exponential amplifier (DSX-AMP) architecture. Each of the DSX-AMPs comprises a variable attenuator of 0 dB to −48.4 dB followed by a high speed, fixed-gain amplifier. The attenuator is based on a 7-stage R-1.5R ladder network. The attenuation between tap points is 6.908 dB, and 48.360 dB for the entire ladder network. The DSX-AMP architecture results in 1.8 nV/√Hz input noise spectral density and accepts a ±2.0 V input signal when VOCM is biased at VP/2.

Each independent channel of the AD605 provides a gain range of 48 dB that can be optimized for the application. Gain ranges between −14 dB to +34 dB and 0 dB to +48 dB can be selected by a single resistor between Pin FBK and Pin OUT. The lower and upper gain ranges are determined by shorting Pin FBK to Pin OUT or leaving Pin FBK unconnected, respectively. The two channels of the AD605 can be cascaded to provide 96 dB of very accurate gain range in a monolithic package.

The gain control interface provides an input resistance of approximately 2 MΩ and scale factors from 20 dB/V to 30 dB/V for a VREF input voltage of 2.5 V to 1.67 V, respectively. Note that scale factors up to 40 dB/V are achievable with reduced accuracy for scales above 30 dB/V. The gain scales linearly in dB with control voltages (VGN) of 0.4 V to 2.4 V for the 20 dB/V scale and 0.20 V to 1.20 V for the 40 dB/V scale. When VGN is <50 mV, the amplifier is powered down to draw 1.9 mA. Under normal operation, the quiescent supply current of each amplifier channel is only 18 mA.

The AD605 is available in a 16-lead PDIP and a 16-lead SOIC_N package and is guaranteed for operation over the −40°C to +85°C temperature range.

**Rev. F**

# SPECIFICATIONS

Each channel @ $T_A$ = 25°C, $V_S$ = 5 V, $R_S$ = 50 Ω, $R_L$ = 500 Ω, $C_L$ = 5 pF, $V_{REF}$ = 2.5 V (scaling = 20 dB/V), −14 dB to +34 dB gain range, unless otherwise noted.

**Table 1.**

| | | AD605A | | | AD605B | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Conditions** | **Min** | **Typ** | **Max** | **Min** | **Typ** | **Max** | **Unit** |
| INPUT CHARACTERISTICS | | | | | | | | |
| Input Resistance | | | 175 ± 40 | | | 175 ± 40 | | Ω |
| Input Capacitance | | | 3.0 | | | 3.0 | | pF |
| Peak Input Voltage | At minimum gain | | 2.5 ± 2.5 | | | 2.5 ± 2.5 | | V |
| Input Voltage Noise | VGN = 2.9 V | | 1.8 | | | 1.8 | | nV/√Hz |
| Input Current Noise | VGN = 2.9 V | | 2.7 | | | 2.7 | | pA/√Hz |
| Noise Figure | $R_S$ = 50 Ω, f = 10 MHz, VGN = 2.9 V | | 8.4 | | | 8.4 | | dB |
| | $R_S$ = 200 Ω, f = 10 MHz, VGN = 2.9 V | | 12 | | | 12 | | dB |
| Common-Mode Rejection Ratio | f = 1 MHz, VGN = 2.65 V | | −20 | | | −20 | | dB |
| OUTPUT CHARACTERISTICS | | | | | | | | |
| −3 dB Bandwidth | Constant with gain | | 40 | | | 40 | | MHz |
| Slew Rate | VGN = 1.5 V, output = 1 V step | | 170 | | | 170 | | V/µs |
| Output Signal Range | $R_L$ ≥ 500 Ω | | 2.5 ± 1.5 | | | 2.5 ± 1.5 | | V |
| Output Impedance | f = 10 MHz | | 2 | | | 2 | | Ω |
| Output Short-Circuit Current | | | ±40 | | | ±40 | | mA |
| Harmonic Distortion | VGN = 1 V, $V_{OUT}$ = 1 V p-p | | | | | | | |
| HD2 | f = 1 MHz | | −64 | | | −64 | | dBc |
| HD3 | f = 1 MHz | | −68 | | | −68 | | dBc |
| HD2 | f = 10 MHz | | −51 | | | −51 | | dBc |
| HD3 | f = 10 MHz | | −53 | | | −53 | | dBc |
| Two-Tone Intermodulation Distortion (IMD) | $R_S$ = 0 Ω, VGN = 2.9 V, $V_{OUT}$ = 1 V p-p | | | | | | | |
| | f = 1 MHz | | −72 | | | −72 | | dBc |
| | f = 10 MHz | | −60 | | | −60 | | dBc |
| 1 dB Compression Point | f = 10 MHz, VGN = 2.9 V, output referred | | 15 | | | 15 | | dBm |
| Third-Order Intercept | f = 10 MHz, VGN = 2.9 V, $V_{OUT}$ = 1 V p-p, input referred | | −1 | | | −1 | | dBm |
| Channel-to-Channel Crosstalk | Ch1: VGN = 2.65 V, inputs shorted, Ch2: VGN = 1.5 V (mid gain), f = 1 MHz, $V_{OUT}$ = 1 V p-p | | −70 | | | −70 | | dB |
| Group Delay Variation | 1 MHz < f < 10 MHz, full gain range | | ±2.0 | | | ±2.0 | | ns |
| VOCM Input Resistance | | | 45 | | | 45 | | kΩ |
| ACCURACY | | | | | | | | |
| Absolute Gain Error | | | | | | | | |
| −14 dB to −11 dB | 0.25 V < VGN < 0.40 V | −1.2 | +1.0 | +3.0 | −1.2 | +0.75 | +3.0 | dB |
| −11 dB to +29 dB | 0.40 V < VGN < 2.40 V | −1.0 | ±0.3 | +1.0 | −1.0 | ±0.2 | +1.0 | dB |
| +29 dB to +34 dB | 2.40 V < VGN < 2.65 V | −3.5 | −1.25 | +1.2 | −3.5 | −1.25 | +1.2 | dB |
| Gain Scaling Error | 0.4 V < VGN < 2.4 V | | ±0.25 | | | ±0.25 | | dB/V |
| Output Offset Voltage | $V_{REF}$ = 2.500 V, VOCM = 2.500 V | −30 | ±20 | +30 | −30 | ±20 | +30 | mV |
| Output Offset Variation | $V_{REF}$ = 2.500 V, VOCM = 2.500 V | | 30 | 57 | | 30 | 50 | mV |

| Parameter | Conditions | AD605A | | | AD605B | | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | |
| GAIN CONTROL INTERFACE | | | | | | | | |
| Gain Scaling Factor | $V_{REF}$ = 2.5 V, 0.4 V < VGN < 2.4 V | 19 | 20 | 21 | 19 | 20 | 21 | dB/V |
| | $V_{REF}$ = 1.67 V | | 30 | | | 30 | | dB/V |
| Gain Range | FBK short to OUT | | −14 to +34 | | | −14 to +34 | | dB |
| | FBK open | | 0 to 48 | | | 0 to 48 | | dB |
| Input Voltage (VGN) Range | 20 dB/V, VREF = 2.5 V | | 0.1 to 2.9 | | | 0.1 to 2.9 | | V |
| Input Bias Current | | | −0.4 | | | −0.4 | | µA |
| Input Resistance | | | 2 | | | 2 | | MΩ |
| Response Time | 48 dB gain change | | 0.2 | | | 0.2 | | µs |
| POWER SUPPLY | | | | | | | | |
| Supply Voltage | | 4.5 | 5.0 | 5.5 | 4.5 | 5.0 | 5.5 | V |
| Power Dissipation | | | 90 | | | 90 | | mW |
| VREF Input Resistance | | | 10 | | | 10 | | kΩ |
| Quiescent Supply Current | VPOS | | 18 | 23 | | 18 | 23 | mA |
| Power-Down | VPOS, VGN < 50 mV | | 1.9 | 3.0 | | 1.9 | 3.0 | mA |
| Power-Up Response Time | 48 dB gain, $V_{OUT}$ = 2 V p-p | | 0.6 | | | 0.6 | | µs |
| Power-Down Response Time | | | 0.4 | | | 0.4 | | µs |

# ABSOLUTE MAXIMUM RATINGS

**Table 2.**

| Parameter | Rating |
|---|---|
| Supply Voltage $+V_S$ | |
| Pin 12, Pin 13 (with Pin 4, Pin 5 = 0 V) | 6.5 V |
| Input Voltage Pin 1 to Pin 3, Pin 6 to Pin 9, Pin 16 | VPOS, 0 V |
| Internal Power Dissipation | |
| 16-Lead PDIP | 1.4 W |
| 16-Lead SOIC_N | 1.2 W |
| Operating Temperature Range | −40°C to +85°C |
| Storage Temperature Range | −65°C to +150°C |
| Lead Temperature, Soldering 60 sec | 300°C |
| Thermal Resistance $\theta_{JA}$ | |
| 16-Lead PDIP | 85°C/W |
| 16-Lead SOIC_N | 100°C/W |

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

## ESD CAUTION

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

# PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

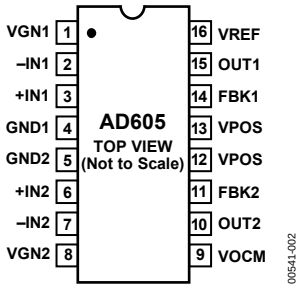
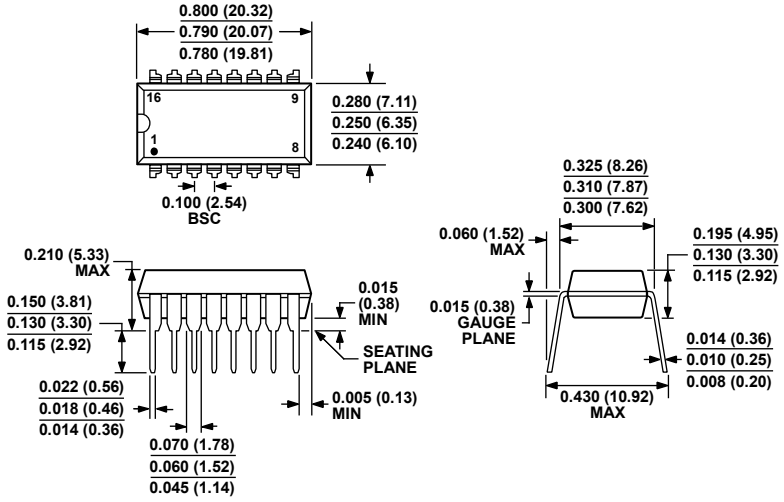



*Figure 2. Pin Configuration*

**Table 3. Pin Function Descriptions**

| Pin No. | Mnemonic | Description |
|---|---|---|
| 1 | VGN1 | CH1 Gain Control Input and Power-Down Pin. If grounded, device is off; otherwise, positive voltage increases gain. |
| 2 | –IN1 | CH1 Negative Input. |
| 3 | +IN1 | CH1 Positive Input. |
| 4 | GND1 | Ground. |
| 5 | GND2 | Ground. |
| 6 | +IN2 | CH2 Positive Input. |
| 7 | –IN2 | CH2 Negative Input. |
| 8 | VGN2 | CH2 Gain Control Input and Power-Down Pin. If grounded, device is off; otherwise, positive voltage increases gain. |
| 9 | VOCM | Input to This Pin Defines Common-Mode Voltage for OUT1 and OUT2. |
| 10 | OUT2 | CH2 Output. |
| 11 | FBK2 | Feedback Pin That Selects Gain Range of CH2. |
| 12 | VPOS | Positive Supply. |
| 13 | VPOS | Positive Supply. |
| 14 | FBK1 | Feedback Pin That Selects Gain Range of CH1. |
| 15 | OUT1 | CH1 Output. |
| 16 | VREF | Input to This Pin Sets Gain Scaling for Both Channels: 2.5 V = 20 dB/V and 1.67 V = 30 dB/V. |

# OUTLINE DIMENSIONS

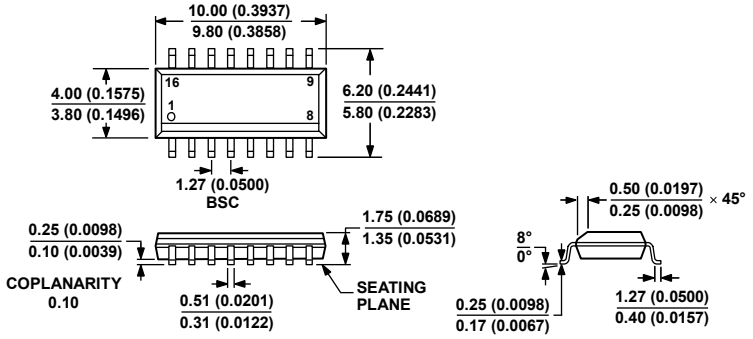



COMPLIANT TO JEDEC STANDARDS MS-001-AB

CONTROLLING DIMENSIONS ARE IN INCHES; MILLIMETER DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF INCH EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN. CORNER LEADS MAY BE CONFIGURED AS WHOLE OR HALF LEADS.

073106-B

*Figure 51. 16-Lead Plastic Dual In-Line Package [PDIP]*
*(N-16)*
*Dimensions shown in inches and (millimeters)*




COMPLIANT TO JEDEC STANDARDS MS-012-AC

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060606-A

*Figure 52. 16-Lead Standard Small Outline Package [SOIC_N]*
*Narrow Body*
*(R-16)*
*Dimensions shown in millimeters and (inches)*

## ORDERING GUIDE

| Model | Temperature Range | Package Description | Package Option |
|---|---|---|---|
| AD605AN | −40°C to +85°C | 16-Lead PDIP | N-16 |
| AD605ANZ[1] | −40°C to +85°C | 16-Lead PDIP | N-16 |
| AD605AR | −40°C to +85°C | 16-Lead SOIC_N | R-16 |
| AD605AR-REEL | −40°C to +85°C | 16-Lead SOIC_N, 13" Tape and Reel | R-16 |
| AD605AR-REEL7 | −40°C to +85°C | 16-Lead SOIC_N, 7" Tape and Reel | R-16 |
| AD605ARZ[1] | −40°C to +85°C | 16-Lead SOIC_N | R-16 |
| AD605ARZ-RL[1] | −40°C to +85°C | 16-Lead SOIC_N, 13" Tape and Reel | R-16 |
| AD605ARZ-R7[1] | −40°C to +85°C | 16-Lead SOIC_N, 7" Tape and Reel | R-16 |
| AD605BN | −40°C to +85°C | 16-Lead PDIP | N-16 |
| AD605BR | −40°C to +85°C | 16-Lead SOIC_N | R-16 |
| AD605BR-REEL | −40°C to +85°C | 16-Lead SOIC_N, 13" Tape and Reel | R-16 |
| AD605BR-REEL7 | −40°C to +85°C | 16-Lead SOIC_N, 7" Tape and Reel | R-16 |
| AD605BRZ[1] | −40°C to +85°C | 16-Lead SOIC_N | R-16 |
| AD605BRZ-RL[1] | −40°C to +85°C | 16-Lead SOIC_N, 13" Tape and Reel | R-16 |
| AD605BRZ-R7[1] | −40°C to +85°C | 16-Lead SOIC_N, 7" Tape and Reel | R-16 |
| AD605-EVALZ[1] | | Evaluation Board | |
| AD605ACHIPS | | DIE | |

[1] Z = RoHS Compliant Part.