# Wide Bandwidth OPERATIONAL TRANSCONDUCTANCE AMPLIFIER (OTA)

## FEATURES

- **Wide Bandwidth (80MHz, Open-Loop, G = +5)**
- **High Slew Rate (900V/µs)**
- **High Transconductance (95mA/V)**
- **External $I_Q$-Control**
- **Low Quiescent Current (5.4mA)**

## APPLICATIONS

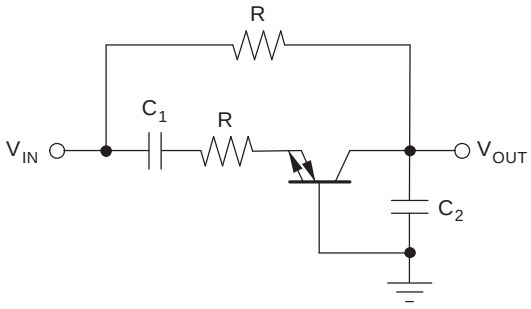
- **Video/Broadcast Equipment**
- **Communications Equipment**
- **High-Speed Data Acquisition**
- **Wideband LED Drivers**
- **Control Loop Amplifiers**
- **Wideband Active Filters**
- **Line Drivers**

## DESCRIPTION

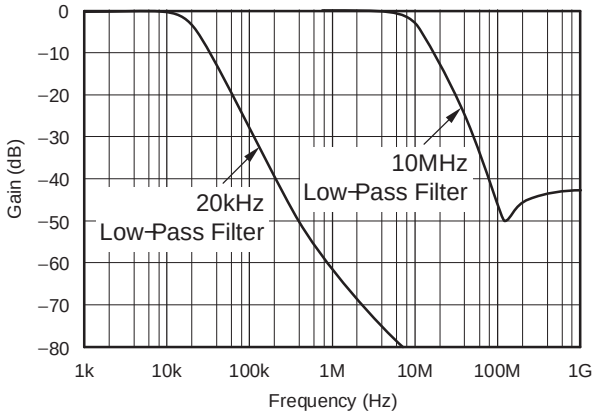
The OPA861 is a versatile monolithic component designed for wide-bandwidth systems, including high performance video, RF and IF circuitry. The OPA861 is a wideband, bipolar operational transconductance amplifier (OTA).

The OTA or voltage-controlled current source can be viewed as an *ideal transistor*. Like a transistor, it has three terminals—a high impedance input (base), a low-impedance input/output (emitter), and the current output (collector). The OPA861, however, is self-biased and bipolar. The output collector current is zero for a zero base-emitter voltage. AC inputs centered about zero produce an output current, which is bipolar and centered about zero. The transconductance of the OPA861 can be adjusted with an external resistor, allowing bandwidth, quiescent current, and gain trade-offs to be optimized.

Used as a basic building block, the OPA861 simplifies the design of AGC amplifiers, LED driver circuits for fiber optic transmission, integrators for fast pulses, fast control loop amplifiers and control amplifiers for capacitive sensors, and active filters. The OPA861 is available in SO-8 and SOT23-6 surface-mount packages.




**Low-Pass Negative Impedance Converter (NIC) Filter**




**Frequency Response of 20kHz and 10MHz Low-Pass NIC Filters**

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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

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

## ORDERING INFORMATION(1)

| PRODUCT | PACKAGE | PACKAGE DESIGNATOR | SPECIFIED TEMPERATURE RANGE | PACKAGE MARKING | ORDERING NUMBER | TRANSPORT MEDIA, QUANTITY |
|---|---|---|---|---|---|---|
| OPA861 | SO-8 | D | –45°C to +85°C | OPA861 | OPA861ID | Rails, 75 |
| | | | | | OPA861IDR | Tape and Reel, 2500 |
| OPA861 | SOT23-6 | DBV | –45°C to +85°C | N5R | OPA861IDBVT | Tape and Reel, 250 |
| | | | | | OPA861IDBVR | Tape and Reel, 3000 |

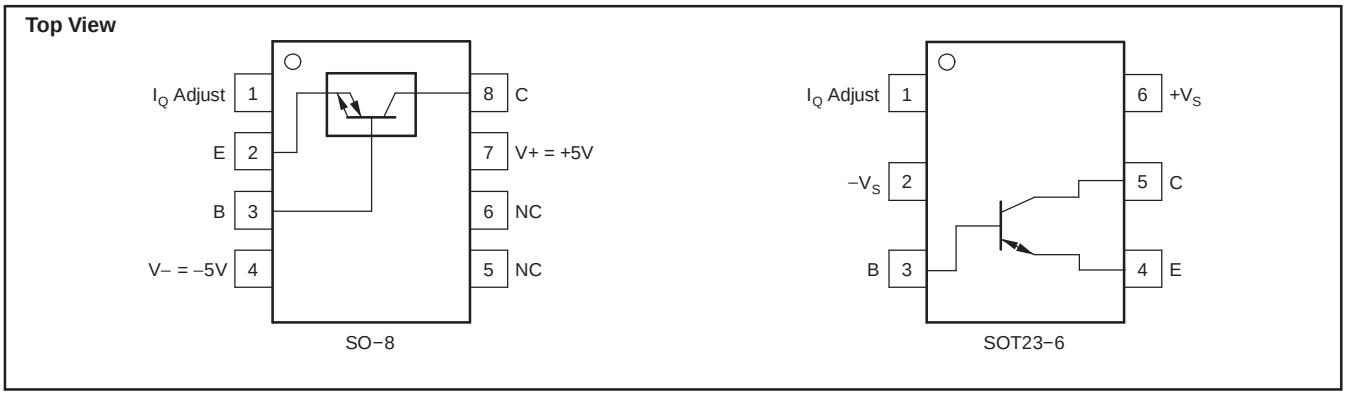
(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

## ABSOLUTE MAXIMUM RATINGS(1)

| | |
|---|---|
| Power Supply | ±6.5$V_{DC}$ |
| Internal Power Dissipation | See Thermal Information |
| Differential Input Voltage | ±1.2V |
| Input Common-Mode Voltage Range | ±$V_S$ |
| Storage Temperature Range: D | –65°C to +125°C |
| Lead Temperature (soldering, 10s) | +260°C |
| Junction Temperature ($T_J$) | +150°C |
| ESD Rating: | |
| Human Body Model (HBM)(2) | 1500V |
| Charge Device Model (CDM) | 1000V |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operations of the device at these and any other conditions beyond those specified is not supported.
(2) Pin 2 for the SO-8 package > 500V HBM. Pin 4 for the SOT23-6 package > 500V HBM.

## PIN CONFIGURATION





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## ELECTRICAL CHARACTERISTICS: $V_S$ = ±5V

$R_L$ = 500Ω and $R_{ADJ}$ = 250Ω, unless otherwise noted.

| PARAMETER | CONDITIONS | OPA861ID, IDBV | | | | UNITS | MIN/ MAX | TEST LEVEL(1) |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| | | +25°C | +25°C(2) | 0°C to 70°C(3) | –40°C to +85°C(3) | | | |
| **OTA—Open-Loop (see Figure 32)** | | | | | | | | |
| **AC PERFORMANCE** | | | | | | | | |
| Bandwidth | G = +5, $V_O$ = 200mV$_{PP}$, $R_L$ = 500Ω | 80 | 77 | 75 | 74 | MHz | min | B |
| | G = +5, $V_O$ = 1V$_{PP}$ | 80 | | | | MHz | typ | C |
| | G = +5, $V_O$ = 5V$_{PP}$ | 80 | | | | MHz | typ | C |
| Slew Rate | G = +5, $V_O$ = 5V Step | 900 | 860 | 850 | 840 | V/µs | min | B |
| Rise Time and Fall Time | $V_O$ = 1V Step | 4.4 | | | | ns | typ | C |
| Harmonic Distortion | G = +5, $V_O$ = 2V$_{PP}$, 5MHz | | | | | | | |
| 2nd-Harmonic | $R_L$ = 500Ω | –68 | –55 | –54 | –53 | dB | max | B |
| 3rd-Harmonic | $R_L$ = 500Ω | –57 | –52 | –51 | –49 | dB | max | B |
| Base Input Voltage Noise | f > 100kHz | 2.4 | 3.0 | 3.3 | 3.4 | nV/√Hz | max | B |
| Base Input Current Noise | f > 100kHz | 1.7 | 2.4 | 2.45 | 2.5 | pA/√Hz | max | B |
| Emitter Input Current Noise | f > 100kHz | 5.2 | 15.3 | 16.6 | 17.5 | pA/√Hz | max | B |
| **OTA DC PERFORMANCE(4) (see Figure 32)** | | | | | | | | |
| Minimum OTA Transconductance ($g_m$) | $V_O$ = ±10mV, $R_C$ = 50Ω, $R_E$ = 0Ω | 95 | **80** | 77 | 75 | mA/V | min | A |
| Maximum OTA Transconductance ($g_m$) | $V_O$ = ±10mV, $R_C$ = 50Ω, $R_E$ = 0Ω | 95 | **150** | 155 | 160 | mA/V | max | A |
| B-Input Offset Voltage | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | ±3 | **±12** | ±15 | ±20 | mV | max | A |
| Average B-Input Offset Voltage Drift | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | | | ±67 | ±120 | µV/°C | max | B |
| B-Input Bias Current | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | ±1 | **±5** | ±6 | ±6.6 | µA | max | A |
| Average B-Input Bias Current Drift | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | | | ±20 | ±25 | nA/°C | max | B |
| E-Input Bias Current | $V_B$ = 0V, $V_C$ = 0V | ±30 | **±100** | ±125 | ±140 | µA | max | A |
| Average E-Input Bias Current Drift | $V_B$ = 0V, $V_C$ = 0V | | | ±500 | ±600 | nA/°C | max | B |
| C-Output Bias Current | $V_B$ = 0V, $V_C$ = 0V | ±5 | **±18** | ±30 | ±38 | µA | max | A |
| Average C-Output Bias Current Drift | $V_B$ = 0V, $V_C$ = 0V | | | ±250 | ±300 | nA/°C | max | B |
| **OTA INPUT (see Figure 32)** | | | | | | | | |
| B-Input Voltage Range | | ±4.2 | ±3.7 | ±3.6 | ±3.6 | V | min | B |
| B-Input Impedance | | 455 \|\| 2.1 | | | | kΩ \|\| pF | typ | C |
| Min E-Input Resistance | | 10.5 | 12.5 | 13.0 | 13.3 | Ω | max | B |
| Max E-Input Resistance | | 10.5 | 6.7 | 6.5 | 6.3 | Ω | min | B |
| **OTA OUTPUT** | | | | | | | | |
| E-Output Voltage Compliance | $I_E$ = ±1mA | ±4.2 | **±3.7** | ±3.6 | ±3.6 | V | min | A |
| E-Output Current, Sinking/Sourcing | $V_E$ = 0 | ±15 | **±10** | ±9 | ±9 | mA | min | A |
| C-Output Voltage Compliance | $I_C$ = ±1mA | ±4.7 | **±4.0** | ±3.9 | ±3.9 | V | min | A |
| C-Output Current, Sinking/Sourcing | $V_C$ = 0 | ±15 | **±10** | ±9 | ±9 | mA | min | A |
| C-Output Impedance | | 54 \|\| 2 | | | | kΩ \|\| pF | typ | C |

(1) Test levels: (A) 100% tested at +25°C. Over temperature limits set by characterization and simulation. (B) Limits set by characterization and simulation. (C) Typical value only for information.
(2) Junction temperature = ambient for +25°C specifications.
(3) Junction temperature = ambient at low temperature limit; junction temperature = ambient + 7°C at high temperature limit for over temperature specifications.
(4) Current is considered positive out of node.

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## ELECTRICAL CHARACTERISTICS: $V_S$ = ±5V (continued)

$R_L$ = 500Ω and $R_{ADJ}$ = 250Ω, unless otherwise noted.

| | | OPA861ID, IDBV | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| PARAMETER | CONDITIONS | +25°C | +25°C[2] | 0°C to 70°C[3] | –40°C to +85°C[3] | UNITS | MIN/ MAX | TEST LEVEL[1] |
| **POWER SUPPLY** | | | | | | | | |
| Specified Operating Voltage | | ±5 | | | | V | typ | C |
| Maximum Operating Voltage | | | **±6.3** | ±6.3 | ±6.3 | V | max | A |
| Minimum Operating Voltage | | | ±2.0 | ±2.0 | ±2.0 | V | min | B |
| Maximum Quiescent Current | $R_{ADJ}$ = 250Ω | 5.4 | **5.9** | 7.0 | 7.4 | mA | max | A |
| Minimum Quiescent Current | $R_{ADJ}$ = 250Ω | 5.4 | **4.9** | 4.3 | 3.4 | mA | min | A |
| OTA Power-Supply Rejection Ratio (+PSRR) | $\Delta I_C/\Delta V_S$ | ±20 | **±50** | ±60 | ±65 | µA/V | max | A |
| **THERMAL CHARACTERISTICS** | | | | | | | | |
| Specification: ID, IDBV | | –40 to +85 | | | | °C | typ | C |
| Thermal Resistance $\theta_{JA}$ | | | | | | | | |
| D SO-8 | Junction-to-Ambient | +125 | | | | °C/W | typ | C |
| DBV SOT23-6 | Junction-to-Ambient | +150 | | | | °C/W | typ | C |


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## ELECTRICAL CHARACTERISTICS: $V_S$ = +5V

$R_L$ = 500Ω to $V_S$/2 and $R_{ADJ}$ = 250Ω, unless otherwise noted.

| PARAMETER | CONDITIONS | OPA861ID, IDBV | | | | UNITS | MIN/ MAX | TEST LEVEL(1) |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| | | +25°C | +25°C(2) | 0°C to 70°C(3) | –40°C to +85°C(3) | | | |
| **OTA—Open-Loop (see Figure 32)** | | | | | | | | |
| **AC PERFORMANCE** | | | | | | | | |
| Bandwidth | G = +5, $V_O$ = 200mV$_{PP}$, $R_L$ = 500Ω | 73 | 72 | 72 | 70 | MHz | min | B |
| | G = +5, $V_O$ = 1V$_{PP}$ | 73 | | | | MHz | typ | C |
| Slew Rate | G = +5, $V_O$ = 2.5V Step | 410 | 395 | 390 | 390 | V/µs | min | B |
| Rise Time and Fall Time | $V_O$ = 1V Step | 4.4 | | | | ns | typ | C |
| Harmonic Distortion | G = +5, $V_O$ = 2V$_{PP}$, 5MHz | | | | | | | |
| 2nd-Harmonic | $R_L$ = 500Ω | –67 | –55 | –54 | –54 | dB | max | B |
| 3rd-Harmonic | $R_L$ = 500Ω | –57 | –50 | –49 | –48 | dB | max | B |
| Base Input Voltage Noise | f > 100kHz | 2.4 | 3.0 | 3.3 | 3.4 | nV/√Hz | max | B |
| Base Input Current Noise | f > 100kHz | 1.7 | 2.4 | 2.45 | 2.5 | pA/√Hz | max | B |
| Emitter Input Current Noise | f > 100kHz | 5.2 | 15.3 | 16.6 | 17.5 | pA/√Hz | max | B |
| **OTA DC PERFORMANCE(4) (see Figure 32)** | | | | | | | | |
| Minimum OTA Transconductance ($g_m$) | $V_O$ = ±10mV, $R_C$ = 50Ω, $R_E$ = 0Ω | 85 | **70** | 67 | 65 | mA/V | min | A |
| Maximum OTA Transconductance ($g_m$) | $V_O$ = ±10mV, $R_C$ = 50Ω, $R_E$ = 0Ω | 85 | **140** | 145 | 150 | mA/V | max | A |
| B-Input Offset Voltage | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | ±3 | **±12** | ±15 | ±20 | mV | max | A |
| Average B-Input Offset Voltage Drift | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | | | ±67 | ±120 | µV/°C | max | B |
| B-Input Bias Current | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | ±1 | **±5** | ±6 | ±6.6 | µA | max | A |
| Average B-Input Bias Current Drift | $V_B$ = 0V, $R_C$ = 0Ω, $R_E$ = 100Ω | | | ±20 | ±25 | nA/°C | max | B |
| E-Input Bias Current | $V_B$ = 0V, $V_C$ = 0V | ±30 | **±100** | ±125 | ±140 | µA | max | A |
| Average E-Input Bias Current Drift | $V_B$ = 0V, $V_C$ = 0V | | | ±500 | ±600 | nA/°C | max | B |
| C-Output Bias Current | $V_B$ = 0V, $V_C$ = 0V | ±15 | | | | µA | typ | C |
| **OTA INPUT (see Figure 32)** | | | | | | | | |
| Most Positive B-Input Voltage | | 4.2 | 3.7 | 3.6 | 3.6 | V | min | B |
| Least Positive B-Input Voltage | | 0.8 | 1.3 | 1.4 | 1.4 | V | max | B |
| B-Input Impedance | | 455 \|\| 2.1 | | | | kΩ \|\| pF | typ | C |
| Min E-Input Resistance | | 11.8 | 14.4 | 14.9 | 15.4 | Ω | max | B |
| Max E-Input Resistance | | 11.8 | 7.1 | 6.9 | 6.7 | Ω | min | B |
| **OTA OUTPUT** | | | | | | | | |
| Maximum E-Output Voltage Compliance | $I_E$ = ±1mA | 4.2 | **3.7** | 3.6 | 3.6 | V | min | A |
| Minimum E-Output Voltage Compliance | $I_E$ = ±1mA | 0.8 | **1.3** | 1.4 | 1.4 | V | max | A |
| E-Output Current, Sinking/Sourcing | $V_E$ = 0 | ±8 | **±7** | ±6.5 | ±6.5 | mA | min | A |
| Maximum C-Output Voltage Compliance | $I_C$ = ±1mA | 4.7 | **4.0** | 3.9 | 3.9 | V | min | A |
| Minimum C-Output Voltage Compliance | $I_C$ = ±1mA | 0.3 | **1.0** | 1.1 | 1.1 | V | max | A |
| C-Output Current, Sinking/Sourcing | $V_C$ = 0 | ±8 | **±7** | ±6.5 | ±6.5 | mA | min | A |
| C-Output Impedance | | 54 \|\| 2 | | | | kΩ \|\| pF | typ | C |

(1) Test levels: (A) 100% tested at +25°C. Over temperature limits set by characterization and simulation. (B) Limits set by characterization and simulation. (C) Typical value only for information.
(2) Junction temperature = ambient for +25°C specifications.
(3) Junction temperature = ambient at low temperature limit; junction temperature = ambient + 3°C at high temperature limit for over temperature specifications.
(4) Current is considered positive out of node.

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## ELECTRICAL CHARACTERISTICS: $V_S$ = +5V (continued)

$R_L$ = 500Ω to $V_S$/2 and $R_{ADJ}$ = 250Ω, unless otherwise noted.

| PARAMETER | CONDITIONS | OPA861ID, IDBV | | | | UNITS | MIN/ MAX | TEST LEVEL[1] |
|---|---|---|---|---|---|---|---|---|
| | | TYP | MIN/MAX OVER TEMPERATURE | | | | | |
| | | +25°C | +25°C[2] | 0°C to 70°C[3] | –40°C to +85°C[3] | | | |
| **POWER SUPPLY** | | | | | | | | |
| Specified Operating Voltage | | 5 | | | | V | typ | C |
| Maximum Operating Voltage | | | **12.6** | 12.6 | 12.6 | V | max | A |
| Minimum Operating Voltage | | | 4 | 4 | 4 | V | min | B |
| Maximum Quiescent Current | $R_{ADJ}$ = 250Ω | 4.7 | **5.2** | 6.0 | 6.4 | mA | max | A |
| Minimum Quiescent Current | $R_{ADJ}$ = 250Ω | 4.7 | **4.2** | 3.4 | 3.0 | mA | min | A |
| OTA Power-Supply Rejection Ratio (+PSRR) | $\Delta I_C/\Delta V_S$ | ±20 | **±50** | ±60 | ±65 | µA/V | max | A |
| **THERMAL CHARACTERISTICS** | | | | | | | | |
| Specification: ID, IDBV | | –40 to +85 | | | | °C | typ | C |
| Thermal Resistance $\theta_{JA}$ | | | | | | | | |
| D SO-8 | Junction-to-Ambient | +125 | | | | °C/W | typ | C |
| DBV SOT23-6 | Junction-to-Ambient | +150 | | | | °C/W | typ | C |


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## TYPICAL CHARACTERISTICS: $V_S$ = ±5V

At $T_A$ = +25°C, $I_Q$ = 5.4mA, and $R_L$ = 500Ω, unless otherwise noted.

**OTA TRANSCONDUCTANCE vs FREQUENCY**

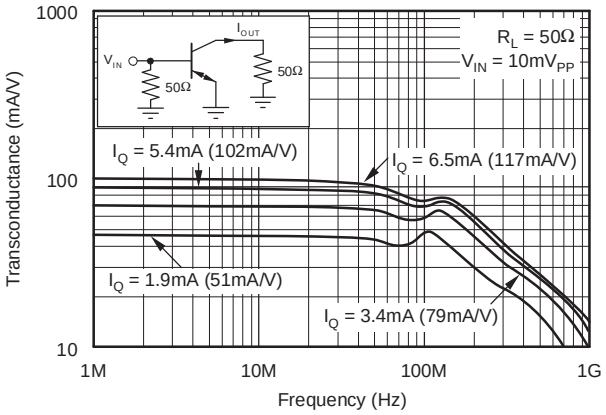


**Figure 1.**

**OTA TRANSCONDUCTANCE vs QUIESCENT CURRENT**

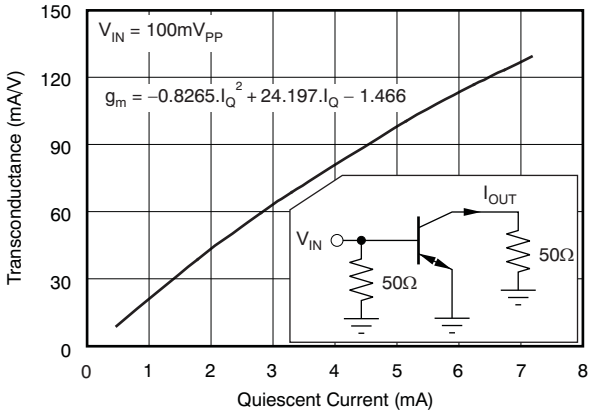


**Figure 2.**

**OTA TRANSCONDUCTANCE vs INPUT VOLTAGE**

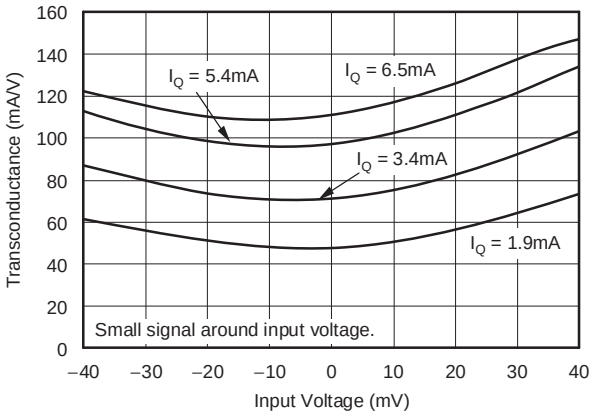


**Figure 3.**

**OTA TRANSFER CHARACTERISTICS**

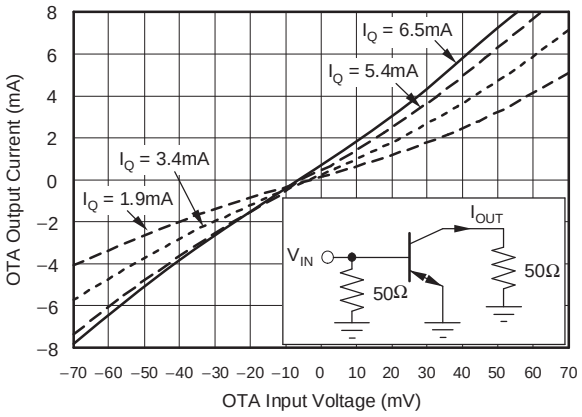


**Figure 4.**

**OTA SMALL-SIGNAL PULSE RESPONSE**

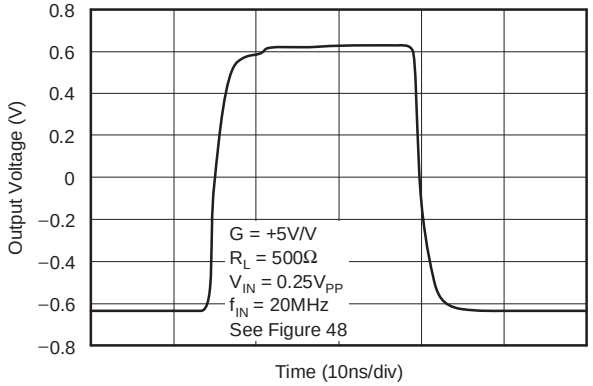


**Figure 5.**

**OTA LARGE-SIGNAL PULSE RESPONSE**

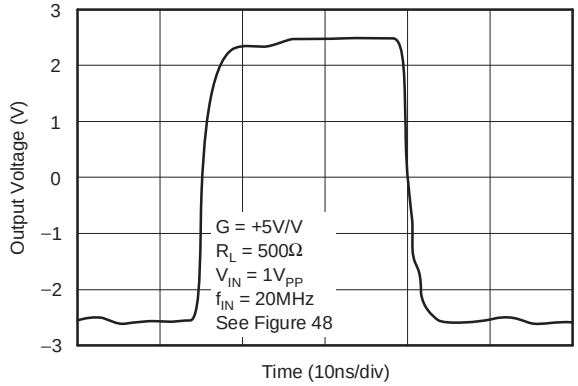


**Figure 6.**

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## TYPICAL CHARACTERISTICS: $V_S$ = ±5V (continued)

At $T_A$ = +25°C, $I_Q$ = 5.4mA, and $R_L$ = 500Ω, unless otherwise noted.

**B-INPUT RESISTANCE vs QUIESCENT CURRENT**

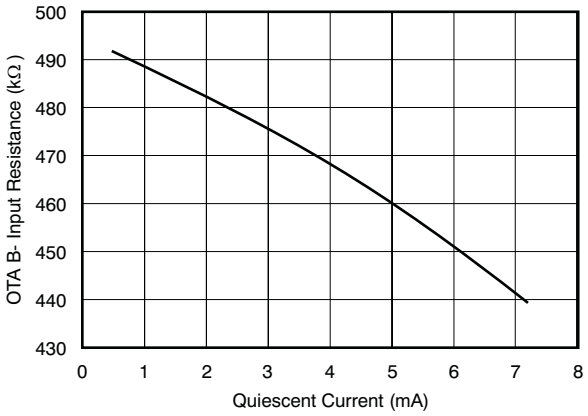


**Figure 7.**

**C-OUTPUT RESISTANCE vs QUIESCENT CURRENT**

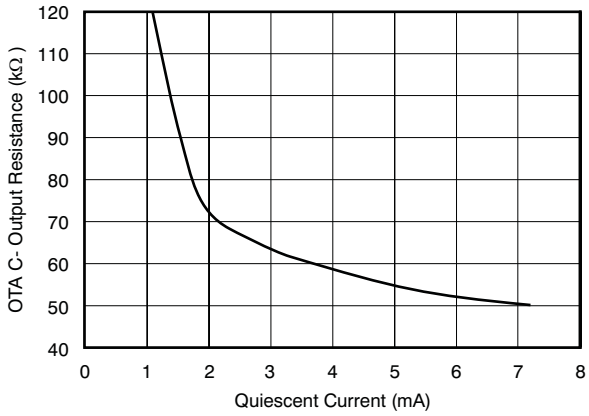


**Figure 8.**

**E-OUTPUT RESISTANCE vs QUIESCENT CURRENT**

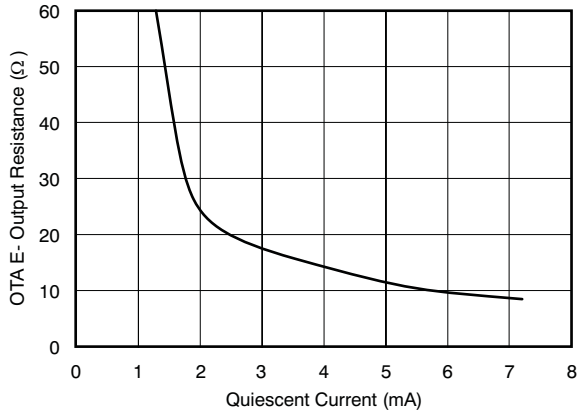


**Figure 9.**

**INPUT VOLTAGE AND CURRENT NOISE DENSITY**

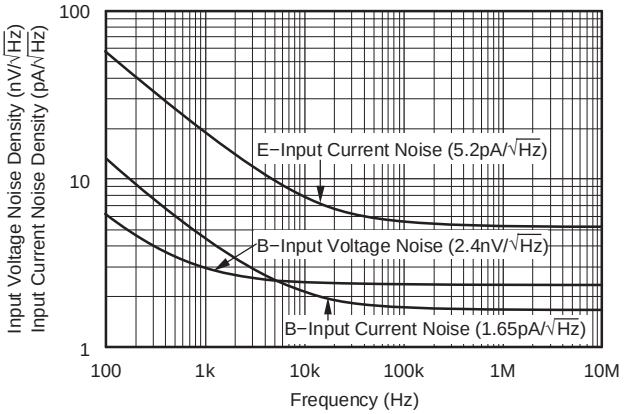


**Figure 10.**

**QUIESCENT CURRENT vs $R_{ADJ}$**

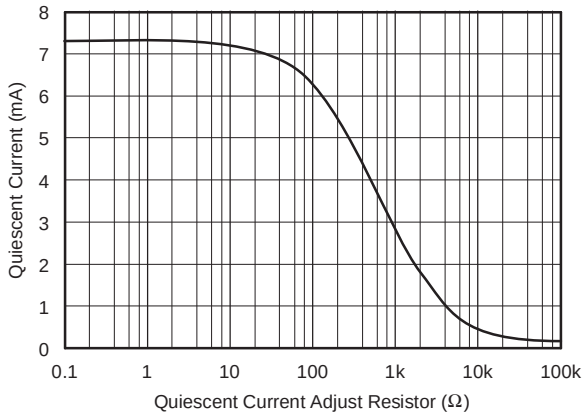


**Figure 11.**

**1MHz OTA VOLTAGE AND CURRENT NOISE DENSITY vs QUIESCENT CURRENT ADJUST RESISTOR**

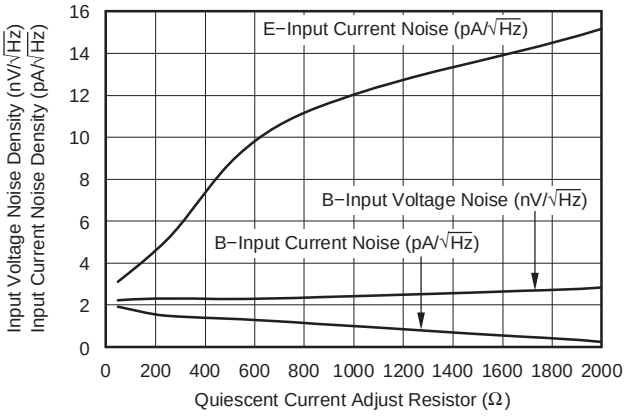


**Figure 12.**


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## TYPICAL CHARACTERISTICS: $V_S$ = ±5V (continued)

At $T_A$ = +25°C, $I_Q$ = 5.4mA, and $R_L$ = 500Ω, unless otherwise noted.

**B-INPUT OFFSET VOLTAGE AND BIAS CURRENT vs TEMPERATURE**

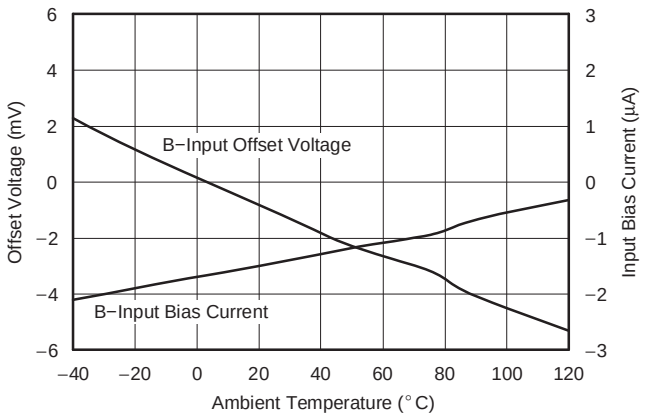


**Figure 13.**

**QUIESCENT CURRENT vs TEMPERATURE**

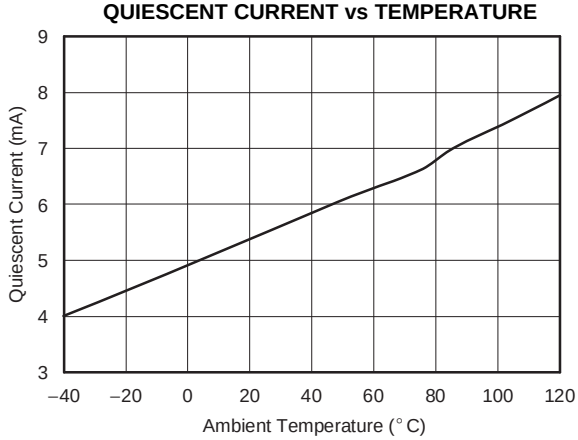


**Figure 14.**

**C-OUTPUT BIAS CURRENT vs TEMPERATURE**

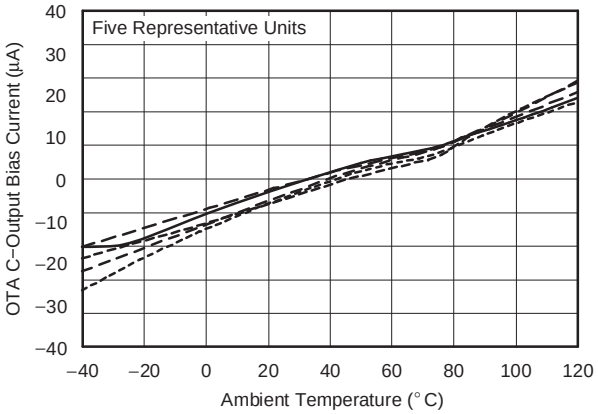


**Figure 15.**

**$I_Q/I_{ADS}$ Ratio vs $R_{ADJ}$**

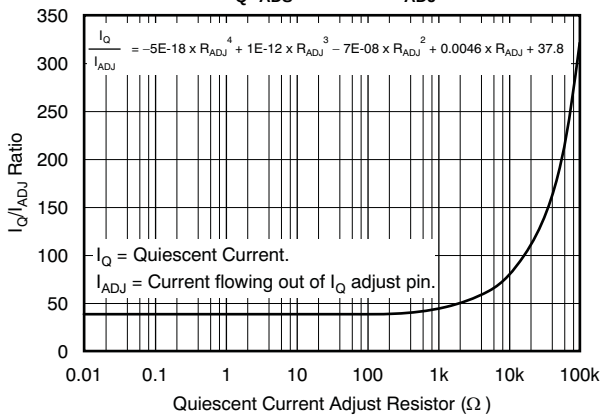


**Figure 16.**

**QUIESCENT CURRENT vs ADJUST PIN BIAS CURRENT**

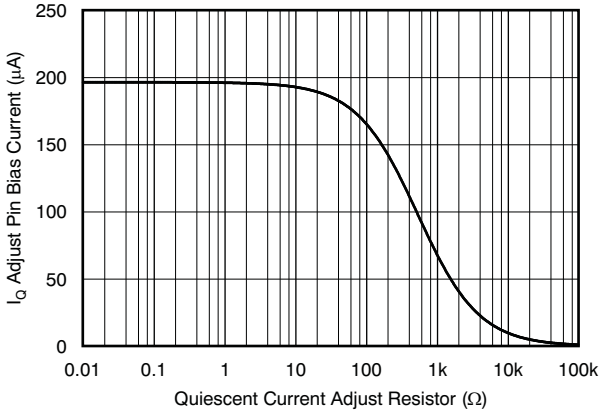


**Figure 17.**

## TYPICAL CHARACTERISTICS: $V_S$ = +5V

At $T_A$ = +25°C, $I_Q$ = 4.7mA, and $R_L$ = 500Ω to $V_S$/2, unless otherwise noted.

**OTA TRANSCONDUCTANCE vs FREQUENCY**

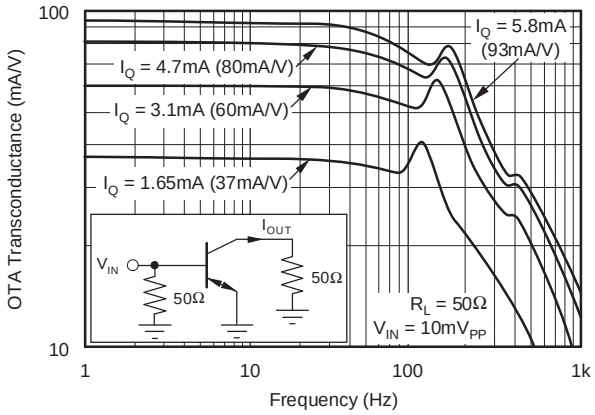


**Figure 18.**

**OTA TRANSCONDUCTANCE vs $I_Q$**

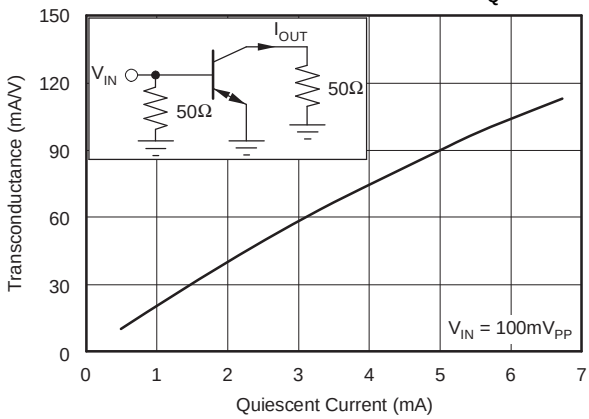


**Figure 19.**

**OTA TRANSCONDUCTANCE vs INPUT VOLTAGE**

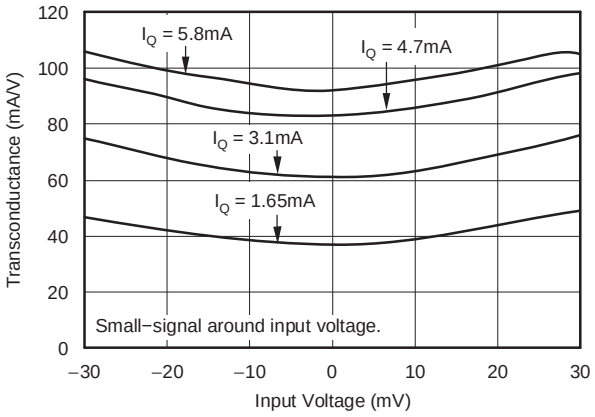


**Figure 20.**

**OTA TRANSFER CHARACTERISTICS**

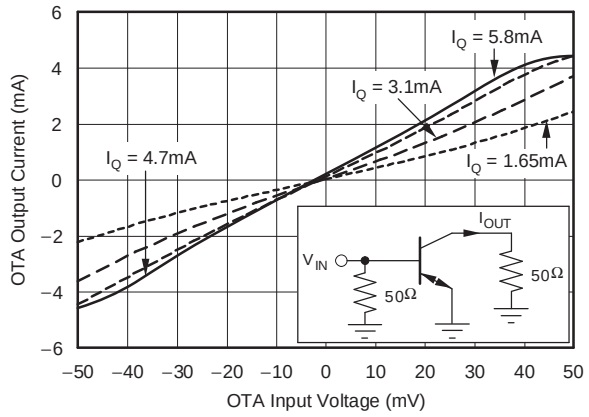


**Figure 21.**

**OTA SMALL-SIGNAL PULSE RESPONSE**

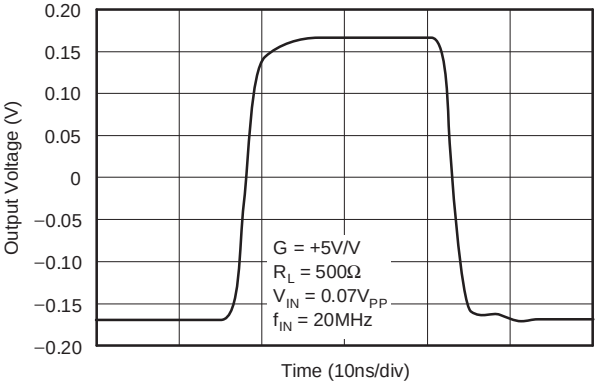


**Figure 22.**

**OTA LARGE-SIGNAL PULSE RESPONSE**

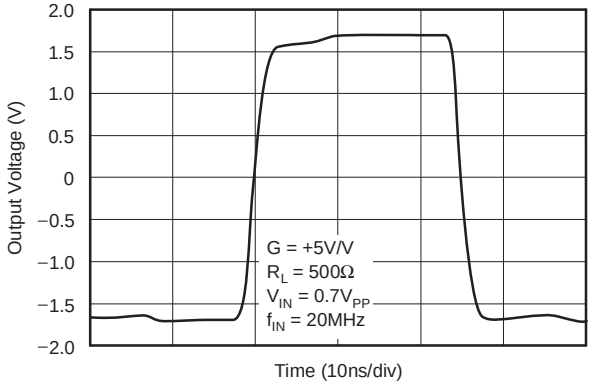


**Figure 23.**


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## TYPICAL CHARACTERISTICS: $V_S$ = +5V (continued)

At $T_A$ = +25°C, $I_Q$ = 4.7mA, and $R_L$ = 500Ω to $V_S$/2, unless otherwise noted.

**B-INPUT RESISTANCE vs QUIESCENT CURRENT**

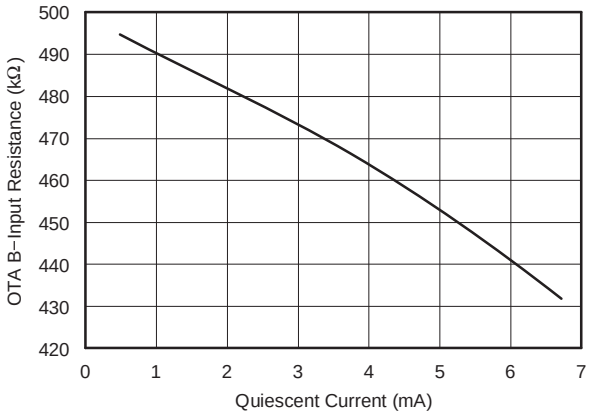


**Figure 24.**

**C-OUTPUT RESISTANCE vs QUIESCENT CURRENT**

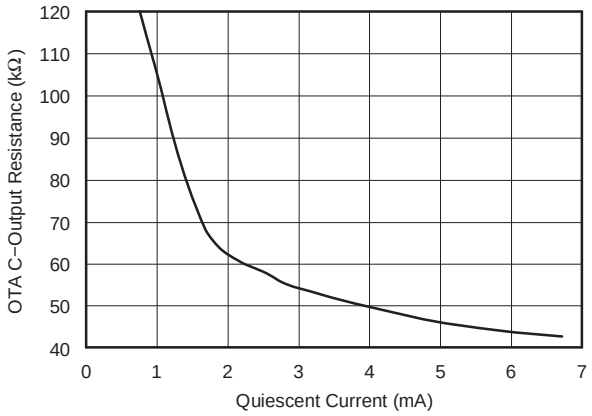


**Figure 25.**

**E-OUTPUT RESISTANCE vs QUIESCENT CURRENT**

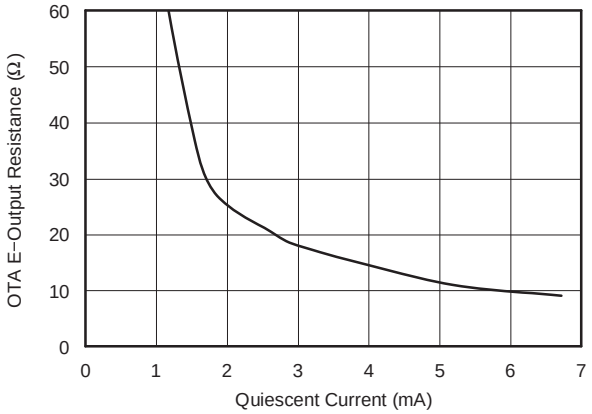


**Figure 26.**

**QUIESCENT CURRENT vs $R_{ADJ}$**

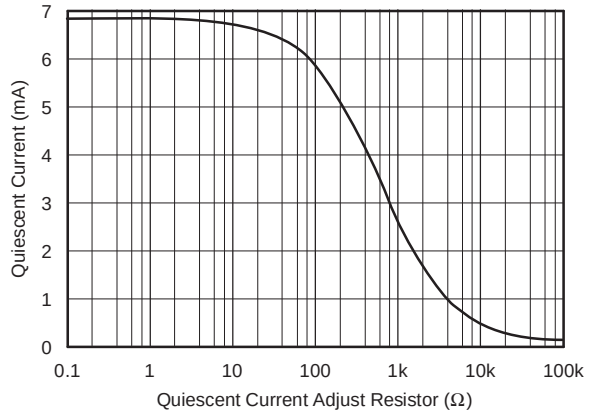


**Figure 27.**

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## APPLICATION INFORMATION

The OPA861 is a versatile monolithic transconductance amplifier designed for wide-bandwidth systems, including high-performance video, RF, and IF circuitry. The operation of the OPA861 is discussed in the *OTA (Operational Transconductance Amplifier)* section of this data sheet. Over the years and depending on the writer, the OTA section of an op amp has been referred to as a Diamond Transistor, Voltage-Controlled Current source, Transconductor, Macro Transistor, or positive second-generation current conveyor (CCII+). Corresponding symbols for these terms are shown in Figure 28.

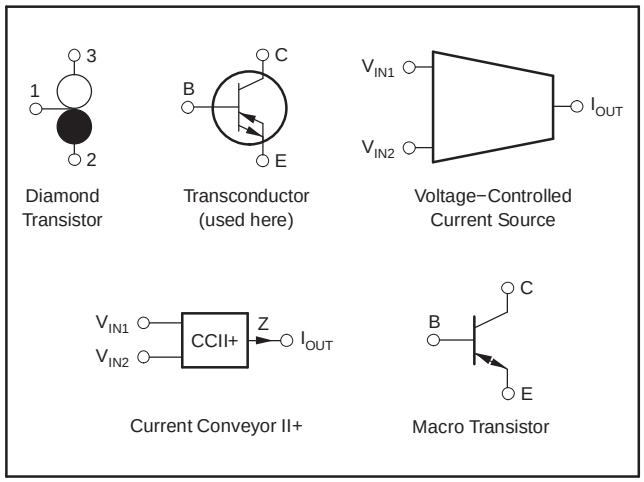


**Figure 28. Symbols and Terms**

Regardless of its depiction, the OTA section has a high-input impedance (B-input), a low-input/output impedance (E-input), and a high-impedance current source output (C-output).

### TRANSCONDUCTANCE (OTA) SECTION—AN OVERVIEW

The symbol for the OTA section is similar to a transistor (see Figure 28). Applications circuits for the OTA look and operate much like transistor circuits—the transistor is also a voltage-controlled current source. Not only does this characteristic simplify the understanding of application circuits, it aids the circuit optimization process as well. Many of the same intuitive techniques used with transistor designs apply to OTA circuits. The three terminals of the OTA are labeled B, E, and C. This labeling calls attention to its similarity to a transistor, yet draws distinction for clarity. While the OTA is similar to a transistor, one essential difference is the sense of the C-output current: it flows out the C terminal for positive B-to-E input voltage and in the C terminal for negative B-to-E input voltage. The OTA offers many advantages over a discrete transistor. The OTA is self-biased, simplifying the design process and reducing component count. In addition, the OTA is far more linear than a transistor. Transconductance of the OTA is constant over a wide range of collector currents—this feature implies a fundamental improvement of linearity.

### BASIC CONNECTIONS

Figure 29 shows basic connections required for operation. These connections are not shown in subsequent circuit diagrams. Power-supply bypass capacitors should be located as close as possible to the device pins. Solid tantalum capacitors are generally best.

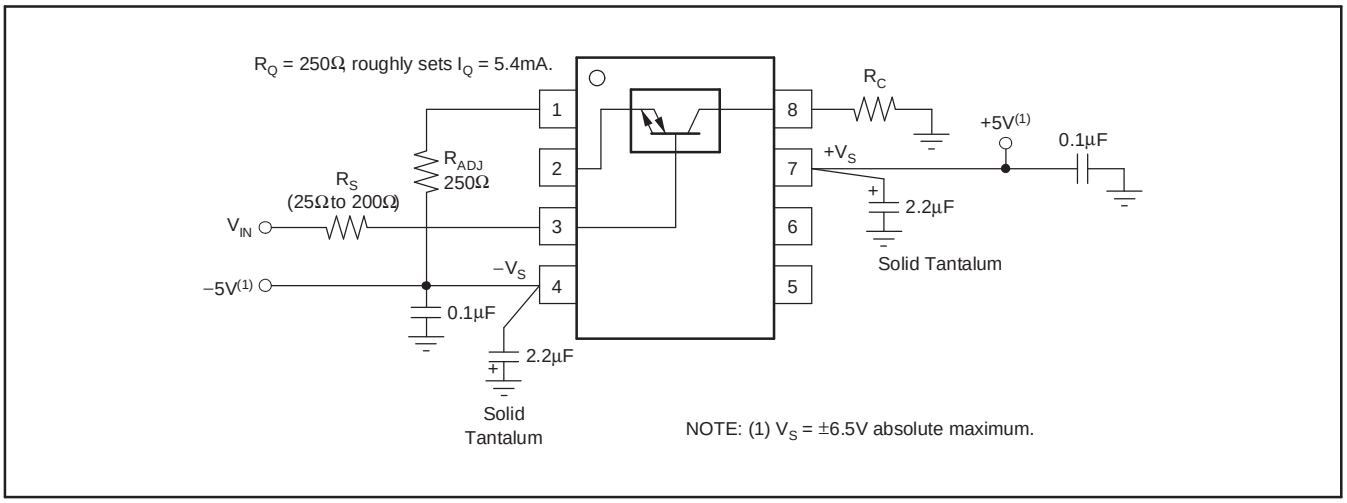


**Figure 29. Basic Connections**


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## QUIESCENT CURRENT CONTROL PIN

The quiescent current of the transconductance portion of the OPA861 is set with a resistor, $R_{ADJ}$, connected from pin 1 to $-V_S$. The maximum quiescent current is 6mA. $R_{ADJ}$ should be set between 50Ω and 1kΩ for optimal performance of the OTA section. This range corresponds to the 5mA quiescent current for $R_{ADJ}$ = 50Ω, and 1mA for $R_{ADJ}$ = 1kΩ. If the $I_Q$ adjust pin is connected to the negative supply, the quiescent current will be set by the 250Ω internal resistor.

Reducing or increasing the quiescent current for the OTA section controls the bandwidth and AC behavior as well as the transconductance. With $R_{ADJ}$ = 250Ω, this sets approximately 5.4mA total quiescent current at 25°C. It may be appropriate in some applications to trim this resistor to achieve the desired quiescent current or AC performance.

**Applications circuits generally do not show the resistor $R_Q$, but it is required for proper operation.**

With a fixed $R_{ADJ}$ resistor, quiescent current increases with temperature (see Figure 11 in the *Typical Characteristics* section). This variation of current with temperature holds the transconductance, $g_m$, of the OTA relatively constant with temperature (another advantage over a transistor).

It is also possible to vary the quiescent current with a control signal. The control loop in Figure 30 shows 1/2 of a REF200 current source used to develop 100mV on $R_1$. The loop forces 125mV to appear on $R_2$. Total quiescent current of the OPA861 is approximately 37 × $I_1$, where $I_1$ is the current made to flow out of pin 1.

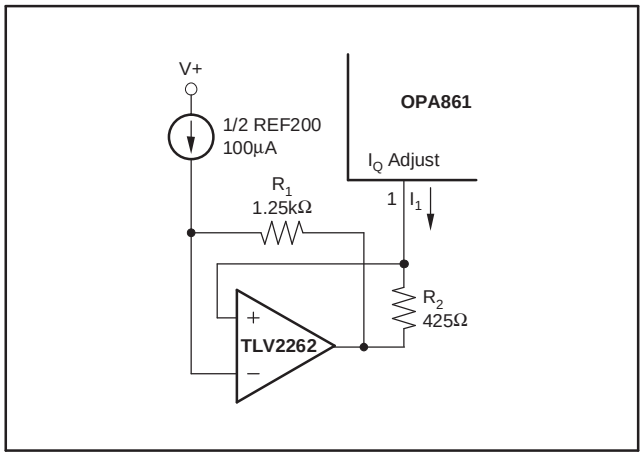


**Figure 30. Optional Control Loop for Setting Quiescent Current**

With this control loop, quiescent current will be nearly constant with temperature. Since this method differs from the temperature-dependent behavior of the internal current source, other temperature-dependent behavior may differ from that shown in the Typical Characteristics. The circuit of Figure 30 will control the $I_Q$ of the OPA861 somewhat more accurately than with a fixed external resistor, $R_Q$. Otherwise, there is no fundamental advantage to using this more complex biasing circuitry. It does, however, demonstrate the possibility of signal-controlled quiescent current. This capability may suggest other possibilities such as AGC, dynamic control of AC behavior, or VCO.

## BASIC APPLICATIONS CIRCUITS

Most applications circuits for the OTA section consist of a few basic types, which are best understood by analogy to a transistor. Used in voltage-mode, the OTA section can operate in three basic operating states—common emitter, common base, and common collector. In the current-mode, the OTA can be useful for analog computation such as current amplifier, current differentiator, current integrator, and current summer.

### Common-E Amplifier or Forward Amplifier

Figure 31 compares the common-emitter configuration for a BJT with the common-E amplifier for the OTA section. There are several advantages in using the OTA section in place of a BJT in this configuration. Notably, the OTA does not require any biasing, and the transconductance gain remains constant over temperature. The output offset voltage is close to 0, compared with several volts for the common-emitter amplifier.

The gain is set in a similar manner as for the BJT equivalent with Equation 1:

$$G = \frac{R_L}{\frac{1}{g_m} + R_E} \quad (1)$$

Just as transistor circuits often use emitter degeneration, OTA circuits may also use degeneration. This option can be used to reduce the effects that offset voltage and offset current might otherwise have on the DC operating point of the OTA. The E-degeneration resistor may be bypassed with a large capacitor to maintain high AC gain. Other circumstances may suggest a smaller value capacitor used to extend or optimize high-frequency performance.

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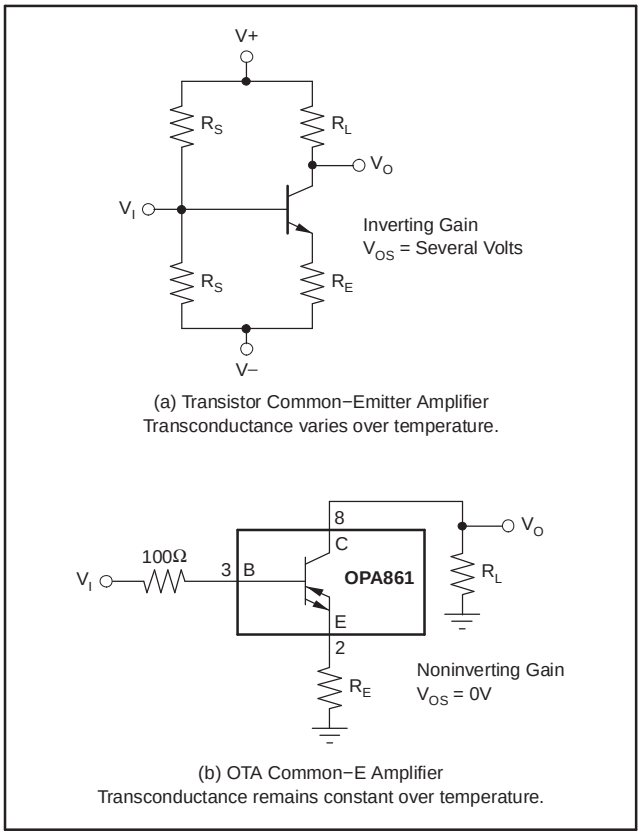


**Figure 31. Common-Emitter vs Common-E Amplifier**

The transconductance of the OTA with degeneration can be calculated by Equation 2:

$$g_{m_deg} = \frac{1}{\frac{1}{g_m} + R_E} \quad (2)$$

A positive voltage at the B-input, pin 3, causes a positive current to flow out of the C-input, pin 8. This gives a noninverting gain where the circuit of Figure 31a is inverting. Figure 31b shows an amplifier connection of the OPA861, the equivalent of a common-emitter transistor amplifier. Input and output can be ground-referenced without any biasing. The amplifier is non-inverting because of the sense of the output current.

The forward amplifier shown in Figure 32 and Figure 33 corresponds to one of the basic circuits used to characterize the OPA861. Extended characterization of this topology appears in the *Typical Characteristics* section of this datasheet.

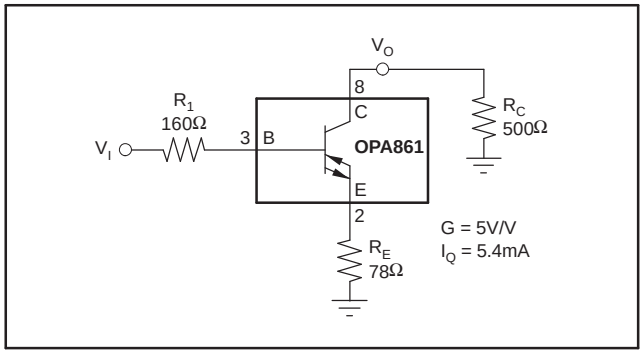


**Figure 32. Forward Amplifier Configuration and Test Circuit**

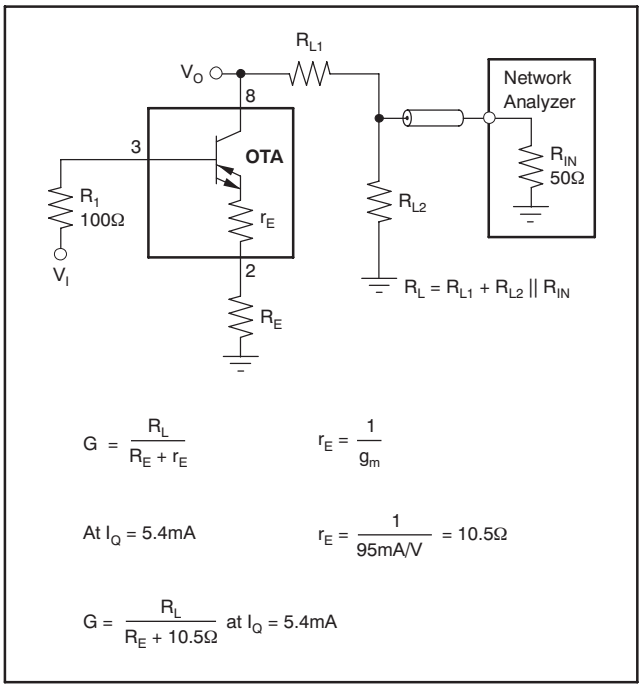


**Figure 33. Forward Amplifier Design Equations**


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### Common-C Amplifier

Figure 34b shows the OPA861 connected as an E-follower—a voltage buffer. It is interesting to notice that the larger the $R_E$ resistor, the closer to unity gain the buffer will be. If the OPA861 is to be used as a buffer, use $R_E \geq 500\Omega$ for best results. For the OPA861 used as a buffer, the gain is given by Equation 3:

$$G = \frac{1}{1 + \frac{1}{g_m \times R_E}} \approx 1 \quad (3)$$

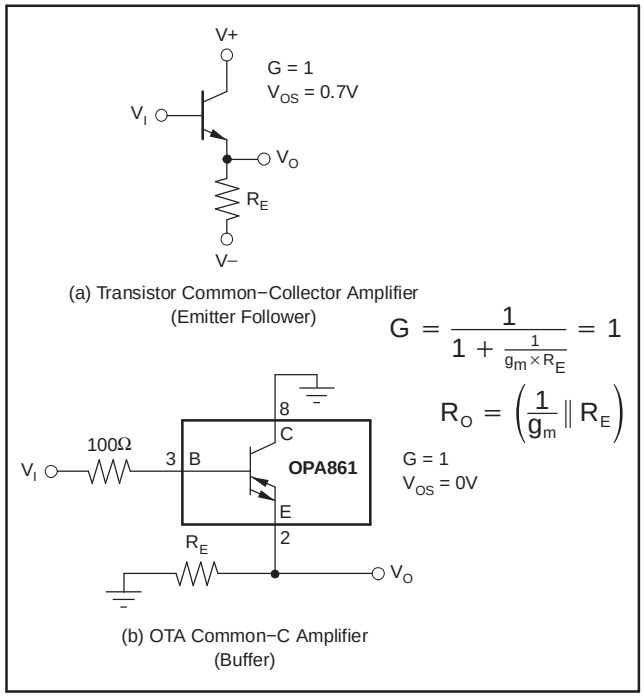



**Figure 34. Common-Collector vs Common-C Amplifier**

A low value resistor in series with the B-input is recommended. This resistor helps isolate trace parasitic from the inputs, reduces any tendency to oscillate, and controls frequency response peaking. Typical resistor values are from 25Ω to 200Ω.

### Common-B Amplifier

Figure 35 shows the Common-B amplifier. This configuration produces an inverting gain and a low impedance input. Equation 4 shows the gain for this configuration.

$$G = \frac{R_L}{R_E + \frac{1}{g_m}} \approx -\frac{R_L}{R_E} \quad (4)$$

This low impedance can be converted to a high impedance by inserting the buffer amplifier in series.

### Current-Mode Analog Computations

As mentioned earlier, the OPA861 can be used advantageously for analog computation. Among the application possibilities are functionality as a current amplifier, current differentiator, current integrator, current summer, and weighted current summer. Table 1 lists these different uses with the associated transfer functions.

These functions can easily be combined to form active filters. Some examples using these current-mode functions are shown later in this document.

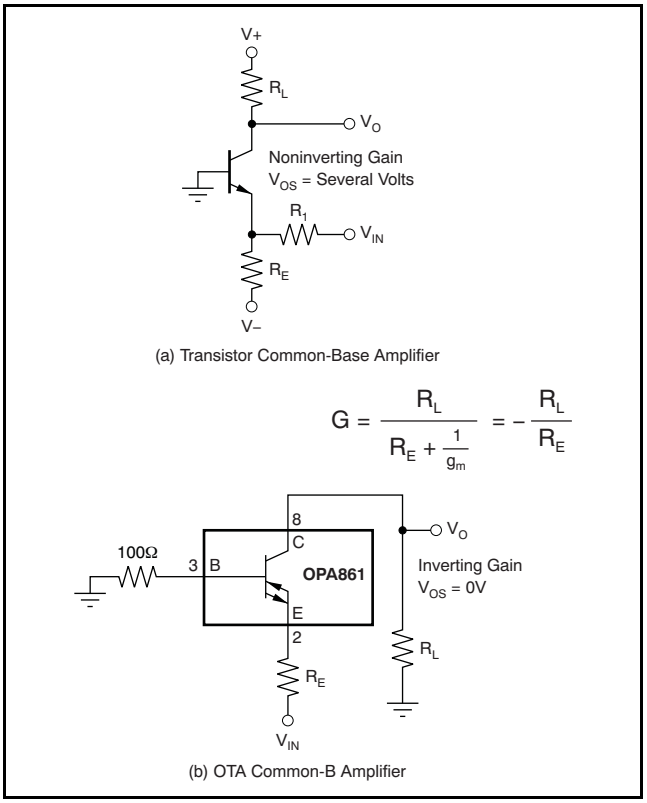
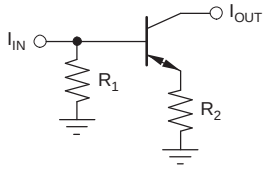
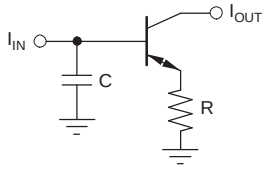
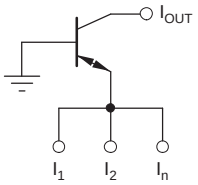
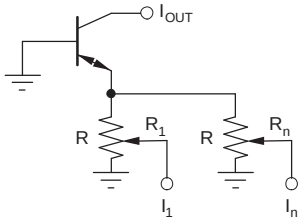



**Figure 35. Common-Base Transistor vs Common-B OTA**

**Table 1. Current-Mode Analog Computation Using the OTA Section**

| FUNCTIONAL ELEMENT | TRANSFER FUNCTION | IMPLEMENTATION WITH THE OTA SECTION |
|---|---|---|
| Current Amplifier | $I_{OUT} = \frac{R_1}{R_2} \times I_{IN}$ |   |
| Current Integrator | $I_{OUT} = \frac{1}{C \times R \times \int I_{IN} dt}$ |   |
| Current Summer | $I_{OUT} = 1 \sum_{j=1}^{n} I_j$ |   |
| Weighted Current Summer | $I_{OUT} = 1 \sum_{j=1}^{n} I_j \times \frac{R_j}{R}$ |   |

## OPA861 APPLICATIONS

### Control-Loop Amplifier

A new type of control loop amplifier for fast and precise control circuits can be designed with the OPA861. The circuit of Figure 36 illustrates a series connection of two voltage control current sources that have an integral (and at higher frequencies, a proportional) behavior versus frequency. The control loop amplifiers show an integrator behavior from DC to the frequency represented by the RC time constant of the network from the C-output to GND. Above this frequency, they operate as an amp with constant gain. The series connection increases the overall gain to about 110dB and thus minimizes the control loop deviation. The differential configuration at the inputs enables one to apply the measured output signal and the reference voltage to two identical high-impedance inputs. The output buffer decouples the C-output of the second OTA in order to insure the AC performance and to drive subsequent output stages.

### DC-Restore Circuit

The OPA861 can be used advantageously with an operational amplifier, here the OPA656, as a DC-restore circuit. Figure 37 illustrates this design. Depending on the collector current of the transconductance amplifier (OTA) of the OPA861, a switching function is realized with the diodes $D_1$ and $D_2$.

When the C-output is sourcing current, the capacitor $C_1$ is being charged. When the C-output is sinking current, $D_1$ is turned off and $D_2$ is turned on, letting the voltage across $C_1$ be discharged through $R_2$.

The condition to charge $C_1$ is set by the voltage difference between $V_{REF}$ and $V_{OUT}$. For the OTA C-output to source current, $V_{REF}$ has to be greater than $V_{OUT}$. The rate of charge of $C_1$ is set by both $R_1$ and $C_1$. The discharge rate is given by $R_2$ and $C_1$.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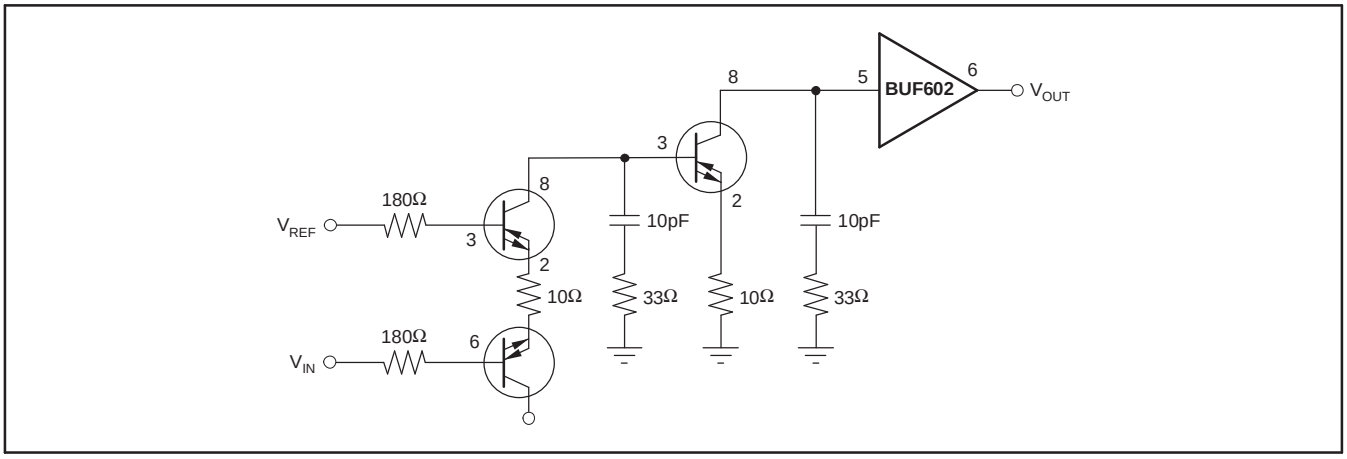


**Figure 36. Control-Loop Amplifier Using Three OPA861s**

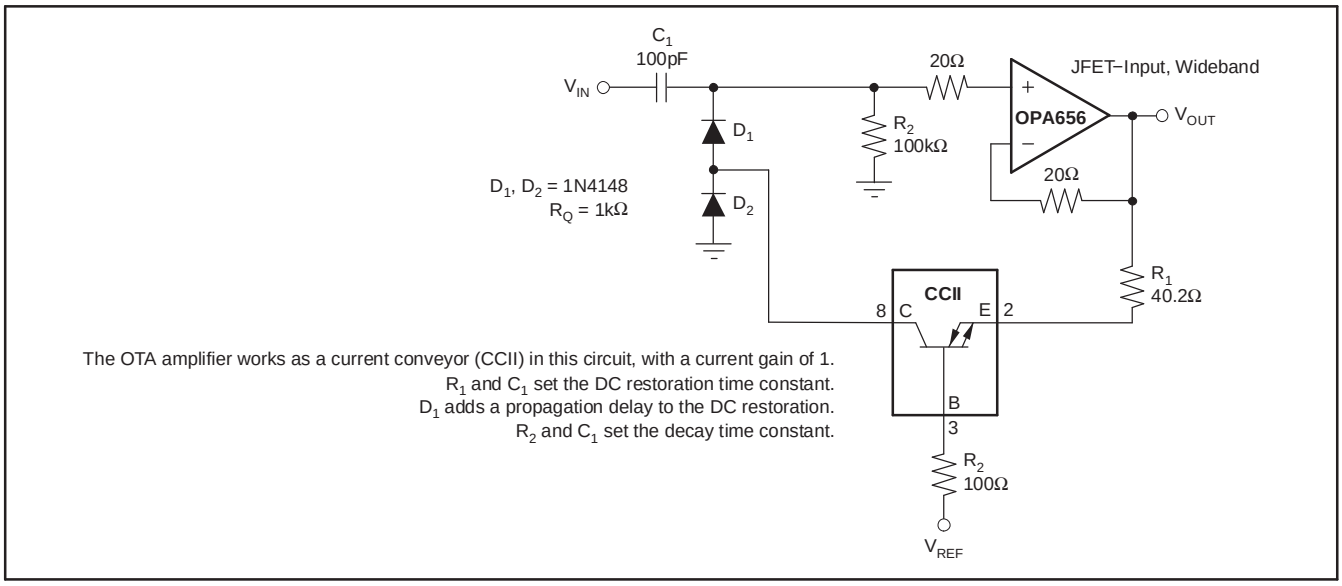


**Figure 37. DC Restorer Circuit**

### Negative Impedance Converter Filter: Low-Pass Filter

The OPA861 can be used as a negative impedance converter to realize the low-pass filer shown in Figure 38.

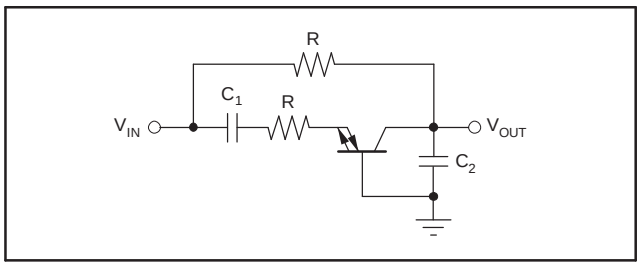


**Figure 38. Low-Pass Negative Impedance Converter Filter**

The transfer function is shown in Equation 5:

$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1 + sC_2R + s^2C_1C_2R^2} \quad (5)$$

with:

$$\omega_0 = \frac{1}{\sqrt{C_1C_2}R}$$

$$Q = \sqrt{\frac{C_1}{C_2}}$$

The input impedance is shown in Equation 6:

$$Z_{IN} = \frac{1}{2sC} + R\frac{1 + sRC}{1 + 2sRC} \quad (6)$$

Figure 39 shows the frequency responses for low-pass, Butterworth filters set at 20kHz and 10MHz.

For the 20kHz filter, set R to 1KΩ and $C_1 = \frac{1}{2} \times C_2 = 5.6\mu F$. For the 10MHz filter, the parasitic capacitance at the output pin needs to be taken into consideration. In the example of Figure 39, the parasitic is 3pF, which gives us the settings of R = 1.13kΩ, $C_1$ = 10pF, and $C_2$ = 17pF.

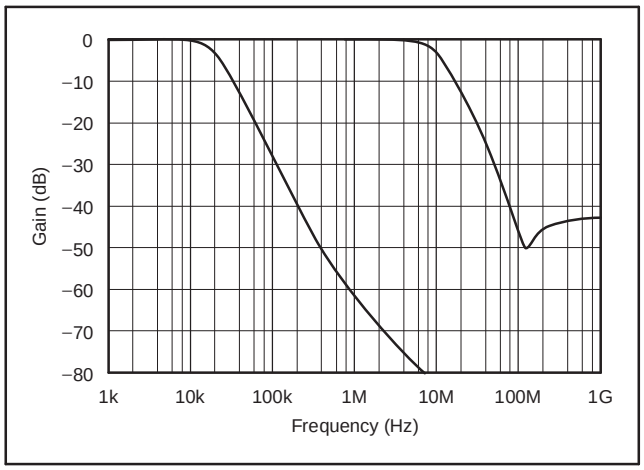


**Figure 39. Small-Signal Frequency Response for a Low-Pass Negative Impedance Converter Filter**

### Differential Line Driver/Receiver

The wide bandwidth and high slew rate of the OPA861 current-mode amplifier make it an ideal line driver. The circuit in Figure 41 makes use of two OPA861s to realize a single-ended to differential conversion. The high-impedance current source output of the OPA861 allows it to drive low-impedance or capacitive loads without series resistances and avoids any attenuation that would have otherwise occured in the resistive network.

The OPA861 used as a differential receiver exhibits excellent common-mode rejection ratio, as can be seen in Figure 40.

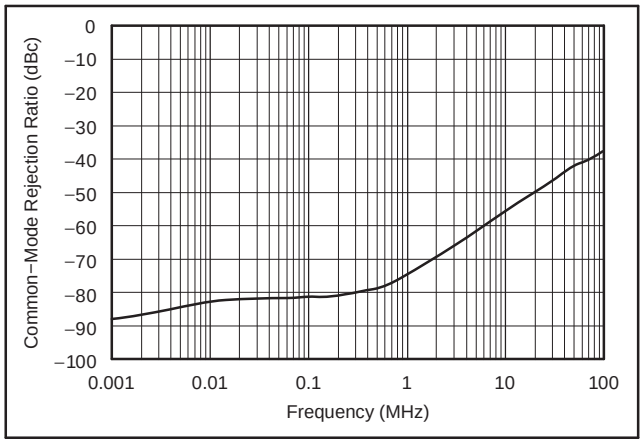


**Figure 40. Differential Driver Common-Mode Rejection Ratio for $2V_{PP}$ Input Signals**

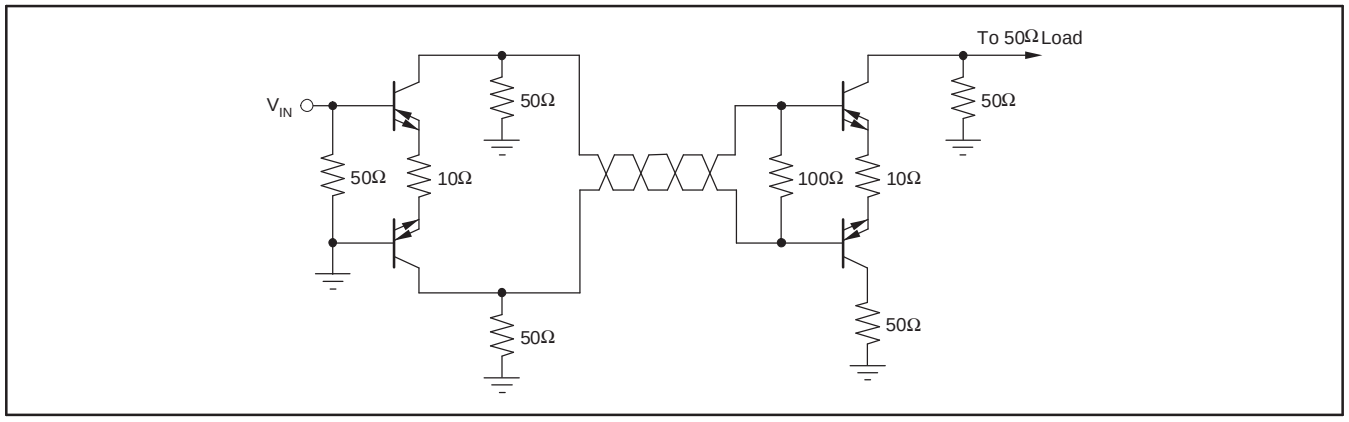


**Figure 41. Twisted-Pair Differential Driver and Receiver with the OPA861**


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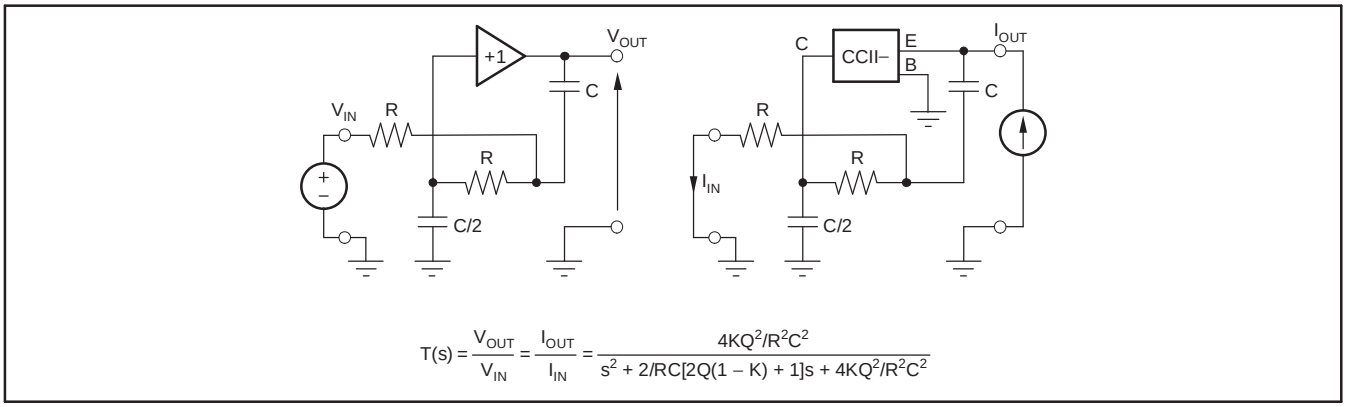
## ACTIVE FILTERS USING THE OPA861 IN CURRENT CONVEYOR STRUCTURE

One further example of the versatility of the Diamond Transistor and Buffer is the construction of high-frequency (> 10MHz) active filters. Here, the Current Conveyor structure, shown in Figure 42, is used with the Diamond Transistor as a Current Conveyor.

The method of converting RC circuit loops with operational amplifiers in Current Conveyor structures is based upon the adjoint network concept. A network is reversible or reciprocal when the transfer function does not change even when the input and output have been exchanged. Most networks, of course, are nonreciprocal. The networks of Figure 43, perform interreciprocally when the input and output are exchanged, while the original network, N, is exchanged for a new network $N_A$. In this case, the transfer function remains the same, and $N_A$ is the adjoing network. It is easy to construct an adjoint network for any given circuit, and these networks are the base for circuits in Current-Conveyor structure. Individual elements can be interchanged according to the list in Figure 44. Voltage sources at the input become short circuits, and the current flowing there becomes the output variable. In contrast, the voltage output becomes the input, which is excitated by a current source. The following equation describes the interreciprocal features of the circuit: $V_{OUT}/V_{IN} = I_{OUT}/I_{IN}$. Resistances and capacitances remain unchanged. In the final step, the operational amplifier with infinite input impedance and 0Ω output impedance is transformed into a current amplifier with 0Ω input impedance and infinite output impedance. A Diamond Transistor with the base at ground comes quite close to an ideal current amplifier. The well-known Sallen-Key low-pass filter with positive feedback, is an example of conversion into Current-Conveyor structure, see Figure 45. The positive gain of the operational amplifier becomes a negative second type of Current Conveyor (CCII), as shown in Figure 42. Both arrangements have identical transfer functions and the same level of sensitivity to deviations. The most recent implementation of active filters in a Current-Conveyor structure produced a second-order Bi-Quad filter. The value of the resistance in the emitter of the Diamond Transistor controls the filter characteristic. For more information, refer to application note SBOS047, *New Ultra High-Speed Circuit Techniques with Analog ICs*.




$$T(s) = \frac{V_{OUT}}{V_{IN}} = \frac{I_{OUT}}{I_{IN}} = \frac{4KQ^2/R^2C^2}{s^2 + 2/RC[2Q(1 - K) + 1]s + 4KQ^2/R^2C^2}$$

**Figure 42. Current Conveyor**

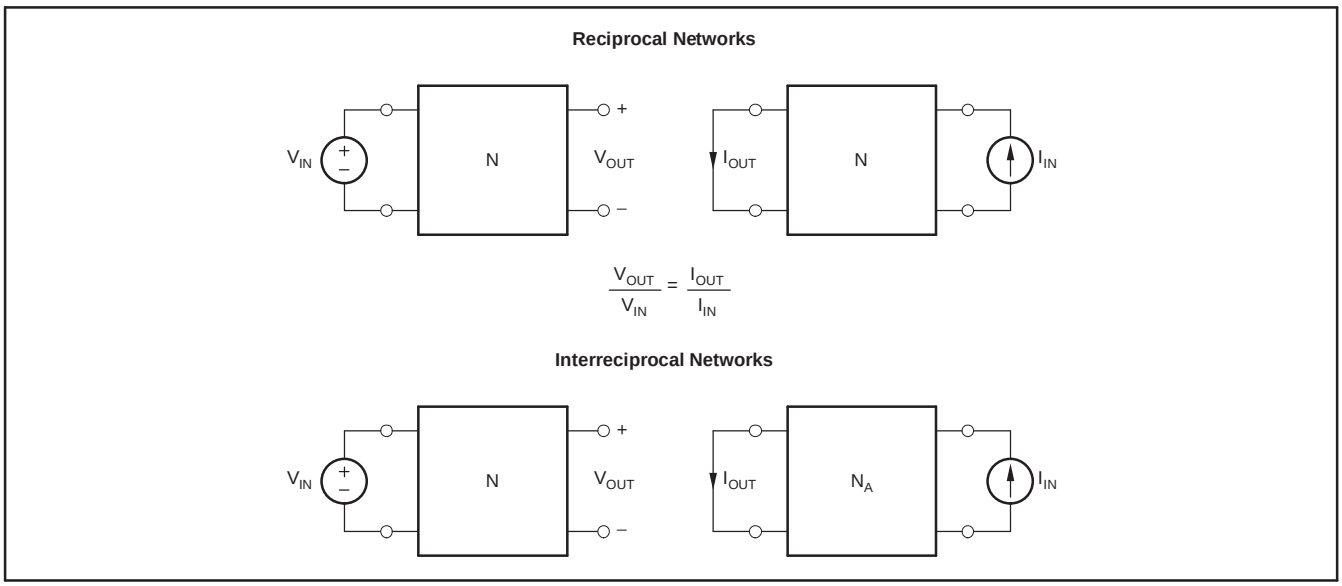



**Figure 43. Networks**

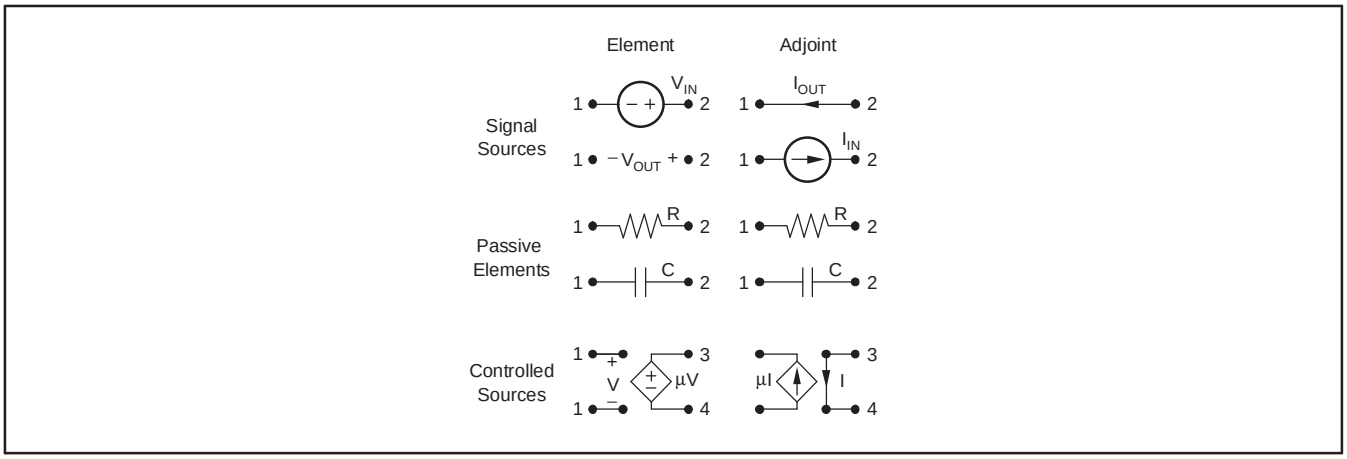



**Figure 44. Individual Elements in the Current Conveyor**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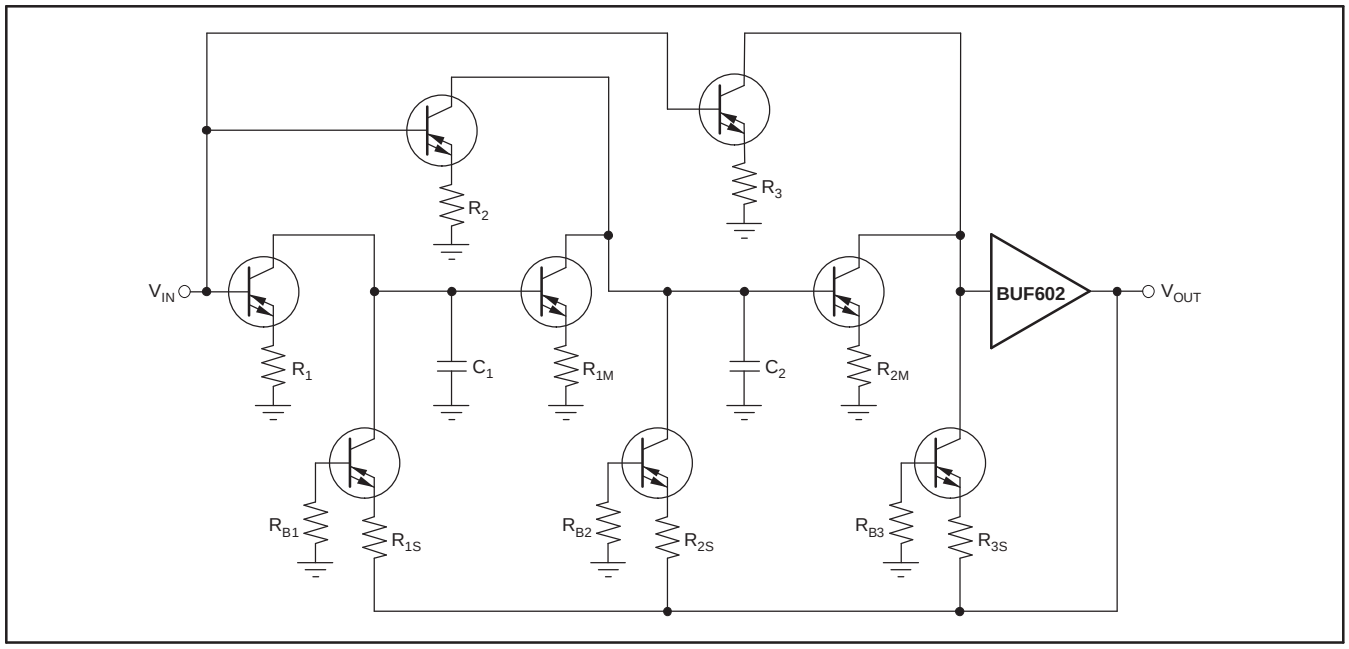


**Figure 45. Universal Active Filter**

### Transfer Function

The transfer function of the universal active filter of Figure 45 is shown in Equation 7.

$$F(p) = \frac{V_{OUT}}{V_{IN}} = \frac{s^2C_1C_2R_{1M}\frac{R_{2M}}{R_3} + sC_1\frac{R_{1M}}{R_2} + \frac{1}{R_1}}{s^2C_1C_2R_{1M}\frac{R_{2M}}{R_{3S}} + sC_1\frac{R_{1M}}{R_{2S}} + \frac{1}{R_{1S}}} \quad (7)$$

### Filter Characteristics

Five filter types can be made with this structure:

- For a low-pass filter, set $R_2 = R_3 = \infty$,
- For a high-pass filter, set $R_1 = R_2 = \infty$,
- For a bandpass filter, set $R_1 = R_3 = \infty$,
- For a band rejection filter, set $R_2 = \infty$; $R_1 = R_3$,
- For an all-pass filter, set $R_1 = R_{1S}$; $R_2 = R_{2S}$; and $R_3 = R_{3S}$.

A few designs for a low-pass filter are shown in Figure 46 and Table 2.

**Table 2. Component Values for Filters Shown In Figure 46**

| $f_O$ | R | $R_O$ | $C_O$ |
|---|---|---|---|
| 1MHz | 150 | 100 | 2nF |
| 20MHz | 150 | 100 | 112.5pF |
| 50MHz | 150 | 100 | 25pF |

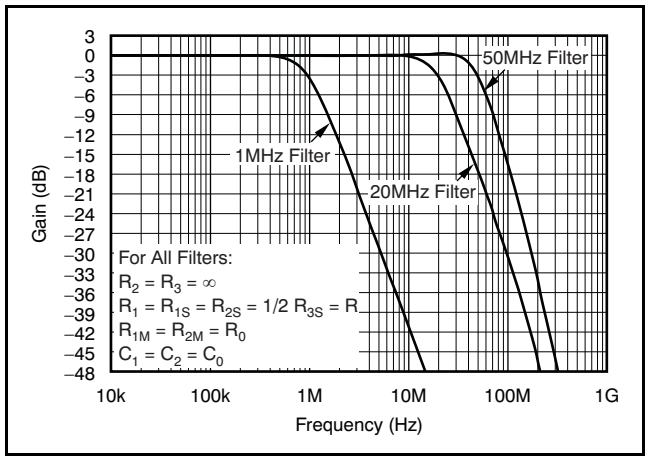


**Figure 46. Butterworth Low-Pass Filter with the Universal Active Filter**

The advantages of building active filters using a Current Conveyor structure are:

- The increase in output resistance of operational amplifiers at high frequencies makes it difficult to construct feedback filter structures (decrease in stop-band attenuation).
- All filter coefficients are represented by resistances, making it possible to adjust the filter frequency response without affecting the filter coefficients.

- The capacitors which determine the frequency are located between the ground and the current source outputs and are thus grounded on one side. Therefore, all parasitic capacitances can be viewed as part of these capacitors, making them easier to comprehend.
- The features which determine the frequency characteristics are currents, which charge the integration capacitors. This situation is similar to the transfer characteristic of the Diamond Transistor.

## High-CMRR, Moderate Precision, Differential I/O ADC Driver

The circuit shown in Figure 47 depicts an ADC driver implemented with two OPA861s. Since the gain is set here by the ratio of the internal 600Ω resistors and $R_E$, its accuracy will only be as good as the input resistor of the ADS5272. The small-signal frequency response for this circuit has 150MHz at –3dB bandwidth for a gain of approximately 5.6dB, as shown in Figure 48. The advantage of this circuit lies in its high CMRR to 100kHz, as shown in Figure 49. This circuit also has more than 10 bits of linearity.

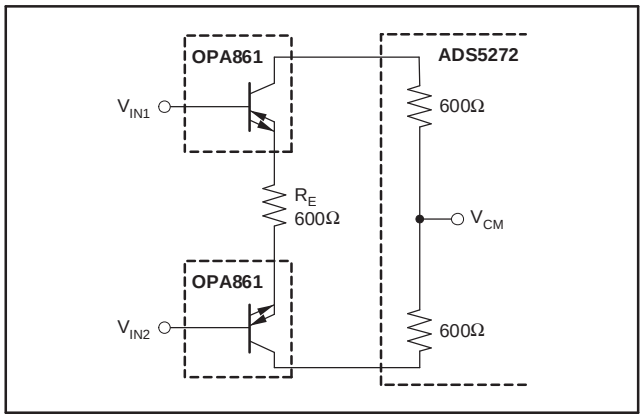


**Figure 47. High CMRR, Moderate Precision, Differential I/O ADC Driver**

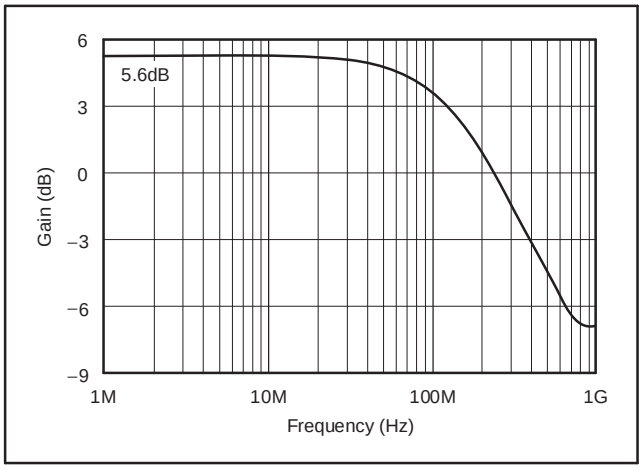


**Figure 48. ADC Driver, Small-Signal Frequency Response**

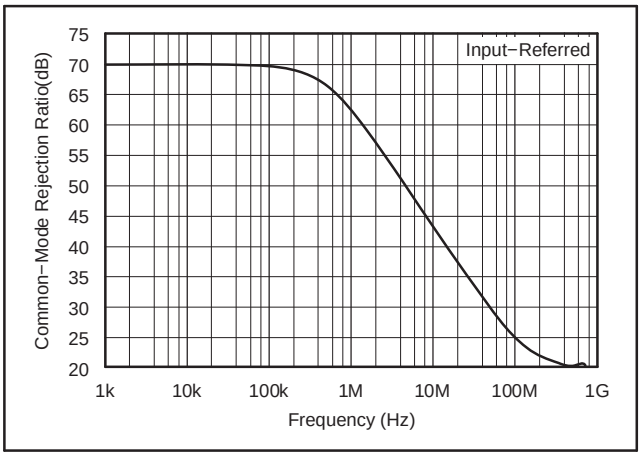


**Figure 49. CMRR of the ADC Driver**


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## DESIGN-IN TOOLS

## DEMONSTRATION BOARDS

A printed circuit board (PCB) is available to assist in the initial evaluation of circuit performance using the OPA861. This module is available free, as an unpopulated PCB delivered with descriptive documentation. The summary information for the board is shown below:

| PRODUCT | PACKAGE | BOARD PART NUMBER | LITERATURE REQUEST NUMBER |
|---|---|---|---|
| OPA861ID | SO-8 | DEM-OTA-SO-1A | SBOU035 |

The board can be requested on the Texas Instruments web site (www.ti.com).

## MACROMODELS AND APPLICATIONS SUPPORT

Computer simulation of circuit performance using SPICE is often useful when analyzing the performance of analog circuits and systems. This principle is particularly true for Video and RF amplifier circuits where parasitic capacitance and inductance can have a major effect on circuit performance. A SPICE model for the OPA861 is available through the Texas Instruments web page (www.ti.com). These models do a good job of predicting small-signal AC and transient performance under a wide variety of operating conditions. They do not do as well in predicting the harmonic distortion. These models do not attempt to distinguish between the package types in their small-signal AC performance.

## NOISE PERFORMANCE

The OTA noise model consists of three elements: a voltage noise on the B-input; a current noise on the B-input; and a current noise on the E-input. Figure 50 shows the OTA noise analysis model with all the noise terms included. In this model, all noise terms are taken to be noise voltage or current density terms in either nV/√Hz or pA/√Hz.

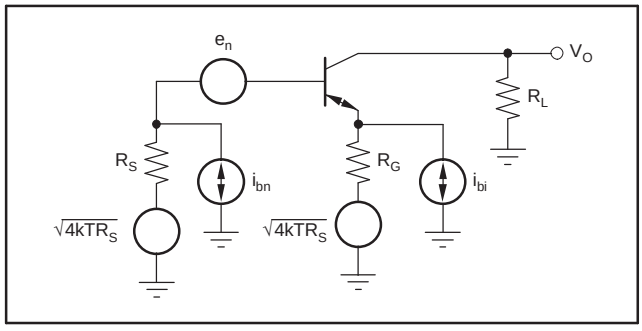


**Figure 50. OTA Noise Analysis Model**

The total output spot noise voltage can be computed as the square root of the sum of all squared output noise voltage contributors. Equation 8 shows the general form for the output noise voltage using the terms shown in Figure 50.

$$e_O = \sqrt{\left[e_n^2 + (R_S i_{bn})^2 + 4kTR_S\right]\left[\frac{R_L}{R_G + \frac{1}{g_m}}\right]^2 + \left[(R_G i_{bi})^2 + 4kTR_G\right]\frac{R_L}{\frac{1}{g_m}}} \quad (8)$$

## THERMAL ANALYSIS

Maximum desired junction temperature will set the maximum allowed internal power dissipation as described below. In no case should the maximum junction temperature be allowed to exceed 150°C.

Operating junction temperature ($T_J$) is given by $T_A + P_D \times \theta_{JA}$. The total internal power dissipation ($P_D$) is the sum of quiescent power ($P_{DQ}$) and additional power dissipated in the output stage ($P_{DL}$) to deliver output current. Quiescent power is simply the specified no-load supply current times the total supply voltage across the part. $P_{DL}$ will depend on the required output signal and load but would, for the OPA861 be at a maximum when the maximum $I_O$ is being driven into a voltage source that puts the maximum voltage across the output stage. Maximum $I_O$ is 15mA times a 9V maximum across the output.

Note that it is the power in the output stage and not into the load that determines internal power dissipation.

As a worst-case example, compute the maximum $T_J$ using an OPA861IDBV in the circuit of Figure 31b operating at the maximum specified ambient temperature of +85°C and driving a –1V voltage reference.

$P_D = 10V \times 5.4mA + (15mA \times 9V) = 185mW$

Maximum $T_J = +85°C + (0.19W \times 150°C/W) = 114°C$.

Although this is still well below the specified maximum junction temperature, system reliability considerations may require lower tested junction temperatures. The highest possible internal dissipation will occur if the load requires current to be forced into the output for positive output voltages or sourced from the output for negative output voltages. This puts a high current through a large internal voltage drop in the output transistors.

## BOARD LAYOUT GUIDELINES

Achieving optimum performance with a high-frequency amplifier like the OPA861 requires careful attention to board layout parasitics and external component types. Recommendations that will optimize performance include:

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**a) Minimize parasitic capacitance** to any AC ground for all of the signal I/O pins. Parasitic capacitance on the inverting input pin can cause instability: on the noninverting input, it can react with the source impedance to cause unintentional bandlimiting. To reduce unwanted capacitance, a window around the signal I/O pins should be opened in all of the ground and power planes around those pins. Otherwise, ground and power planes should be unbroken elsewhere on the board.

**b) Minimize the distance** (< 0.25") from the power-supply pins to high-frequency 0.1µF decoupling capacitors. At the device pins, the ground and power-plane layout should not be in close proximity to the signal I/O pins. Avoid narrow power and ground traces to minimize inductance between the pins and the decoupling capacitors. The power-supply connections should always be decoupled with these capacitors. An optional supply decoupling capacitor (0.1µF) across the two power supplies (for bipolar operation) will improve 2nd-harmonic distortion performance. Larger (2.2µF to 6.8µF) decoupling capacitors, effective at lower frequency, should also be used on the main supply pins. These may be placed somewhat farther from the device and may be shared among several devices in the same area of the PC board.

**c) Careful selection and placement of external components will preserve the high-frequency performance of the OPA861.** Resistors should be a very low reactance type. Surface-mount resistors work best and allow a tighter overall layout. Metal film or carbon composition, axially-leaded resistors can also provide good high-frequency performance. Again, keep their leads and PC board traces as short as possible. Never use wirewound type resistors in a high-frequency application.

**d) Connections to other wideband devices** on the board may be made with short, direct traces or through onboard transmission lines. For short connections, consider the trace and the input to the next device as a lumped capacitive load. Relatively wide traces (50mils to 100mils) should be used, preferably with ground and power planes opened up around them.

**e) Socketing a high-speed part like the OPA861 is not recommended.** The additional lead length and pin-to-pin capacitance introduced by the socket can create an extremely troublesome parasitic network that makes it almost impossible to achieve a smooth, stable frequency response. Best results are obtained by soldering the OPA861 onto the board.

## INPUT AND ESD PROTECTION

The OPA861 is built using a very high-speed complementary bipolar process. The internal junction breakdown voltages are relatively low for these very small geometry devices. These breakdowns are reflected in the *Absolute Maximum Ratings* table. All device pins are protected with internal ESD protection diodes to the power supplies as shown in Figure 51.

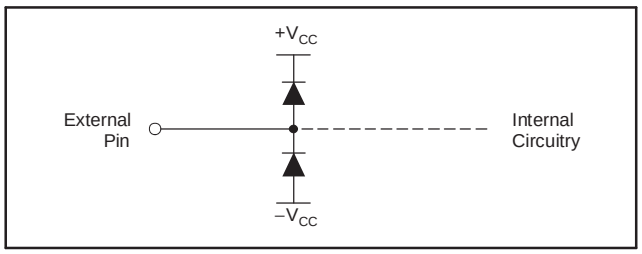


**Figure 51. Internal ESD Protection**

These diodes provide moderate protection to input overdrive voltages above the supplies as well. The protection diodes can typically support 30mA continuous current. Where higher currents are possible (for example, in systems with ±15V supply parts driving into the OPA861), current-limiting series resistors should be added into the two inputs. Keep these resistor values as low as possible since high values degrade both noise performance and frequency response.


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## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from Revision D (August 2006) to Revision E** **Page**

- Changed storage temperature range rating in *Absolute Maximum Ratings* table from –40°C to +125°C to –65°C to +125°C ..... 2

**Changes from Revision C (June 2006) to Revision D** **Page**

- Changed Figure 2 ..... 7
- Changed Figure 7 ..... 8
- Changed Figure 8 ..... 8
- Changed Figure 9 ..... 8
- Added Figure 16 ..... 9
- Added Figure 17 ..... 9
- Changed Equation 7 ..... 21
- Changed final bullet of Filter Characteristics section ..... 21
- Changed Table 2 value in $C_O$ column ..... 21
- Changed Figure 46 ..... 21

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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| OPA861ID | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDBVR | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDBVRG4 | ACTIVE | SOT-23 | DBV | 6 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDBVT | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDBVTG4 | ACTIVE | SOT-23 | DBV | 6 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| OPA861IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |

(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.

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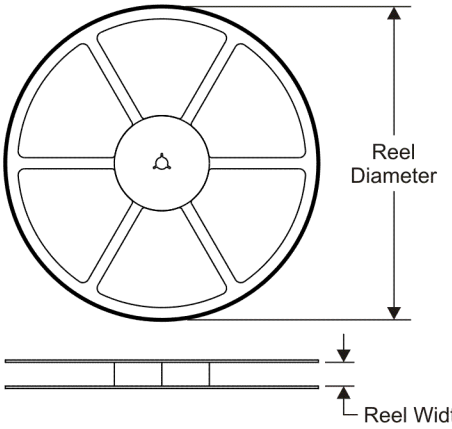
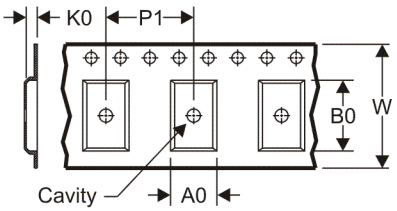
## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

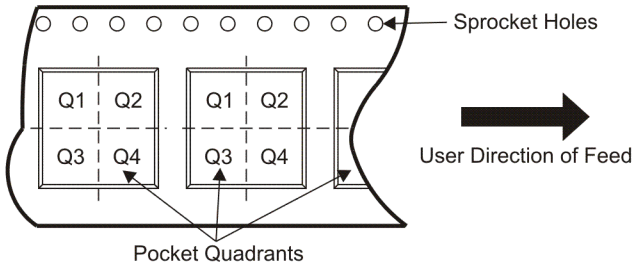



**TAPE DIMENSIONS**




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

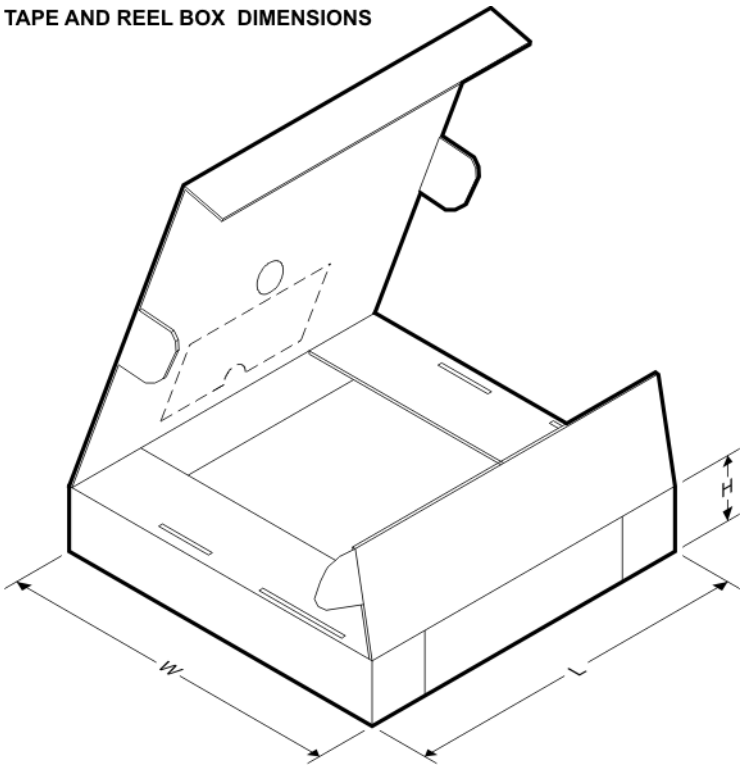
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPA861IDBVR | SOT-23 | DBV | 6 | 3000 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |
| OPA861IDBVT | SOT-23 | DBV | 6 | 250 | 180.0 | 8.4 | 3.2 | 3.1 | 1.39 | 4.0 | 8.0 | Q3 |

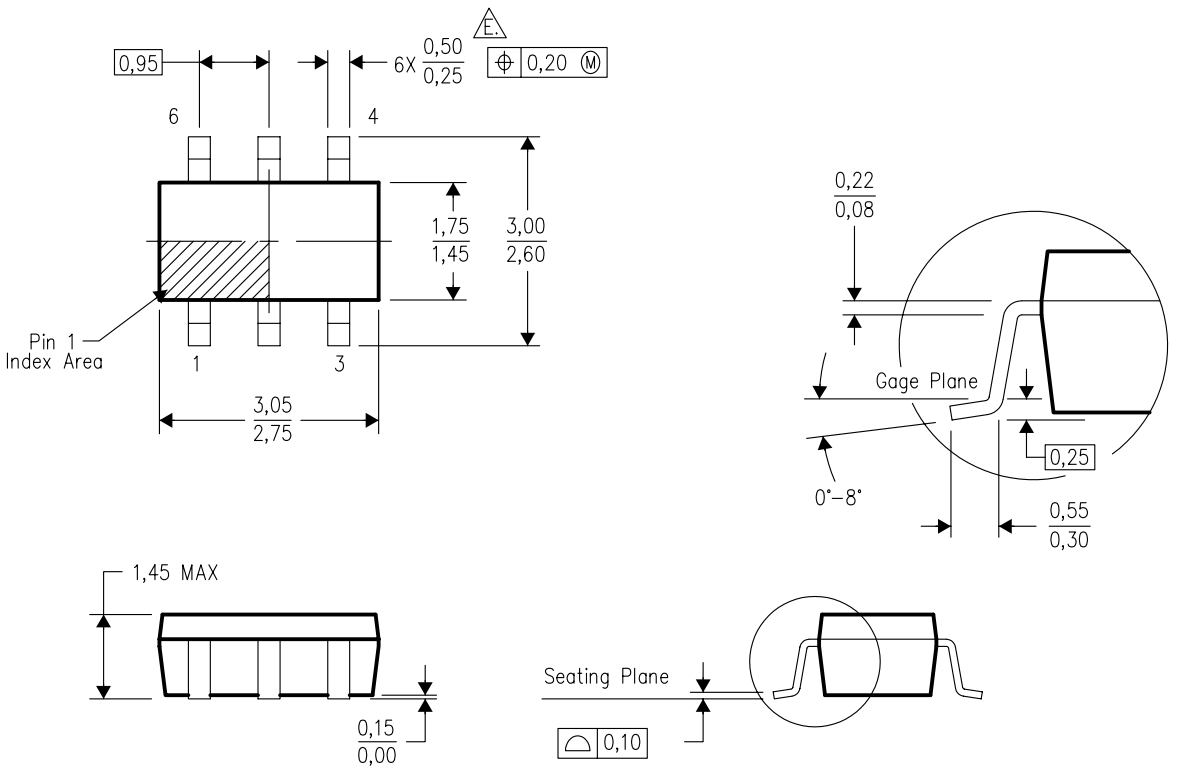
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| OPA861IDBVR | SOT-23 | DBV | 6 | 3000 | 184.0 | 184.0 | 50.0 |
| OPA861IDBVT | SOT-23 | DBV | 6 | 250 | 190.5 | 212.7 | 31.8 |

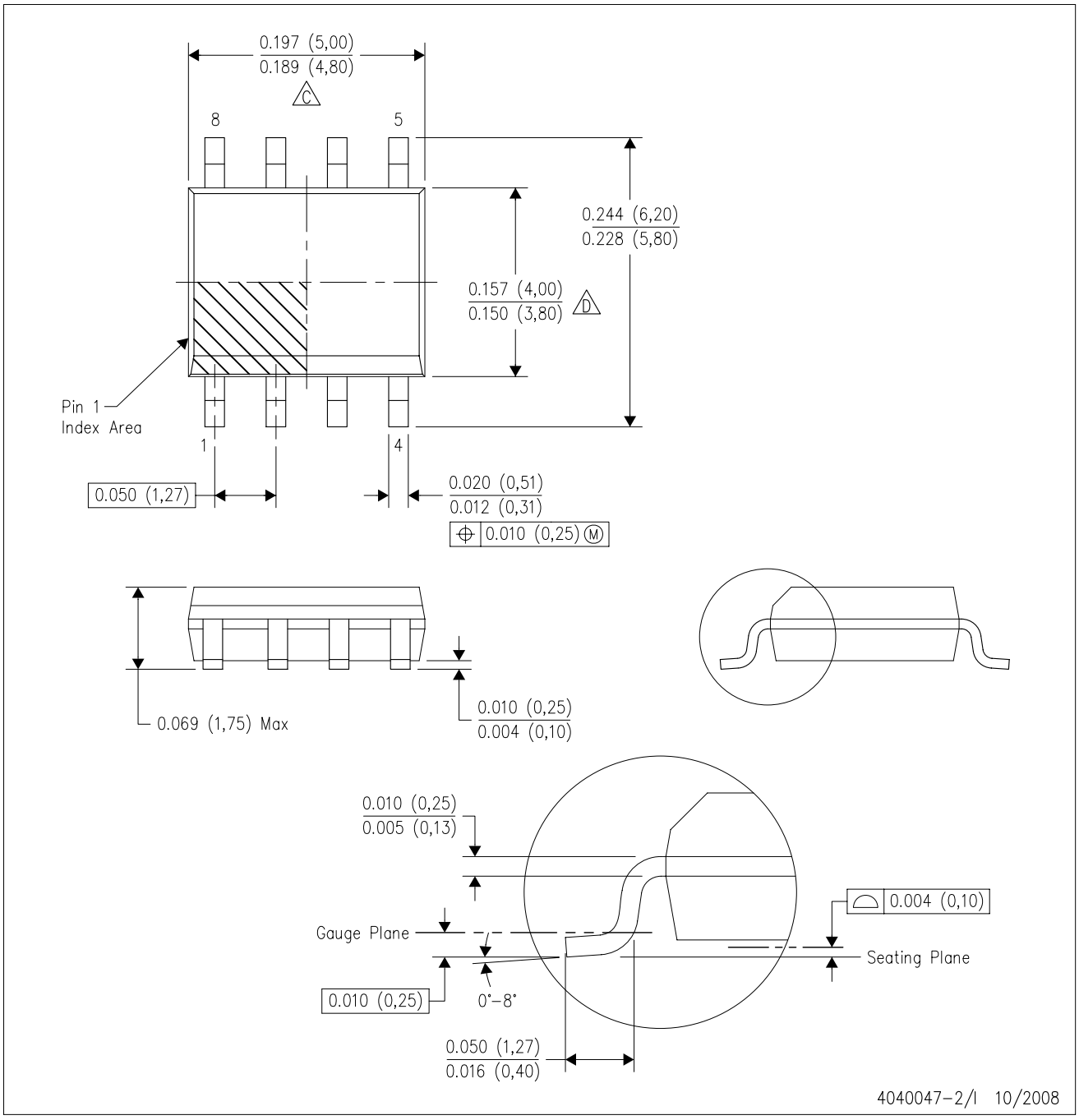
## DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE




4073253–5/K 03/2006

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

D (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE




NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
E. Reference JEDEC MS–012 variation AA.

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