

# RC4156/RC4157

## High Performance Quad Operational Amplifiers

### Features

- Unity gain bandwidth for RC4156 – 3.5 MHz
- Unity gain bandwidth for RC4157 – 19 MHz
- High slew rate for RC4156 – 1.6 V/ $\mu$ S
- High slew rate for RC4157 – 8.0V/ $\mu$ S
- Low noise voltage – 1.4  $\mu$ VRMS
- Indefinite short circuit protection
- No crossover distortion

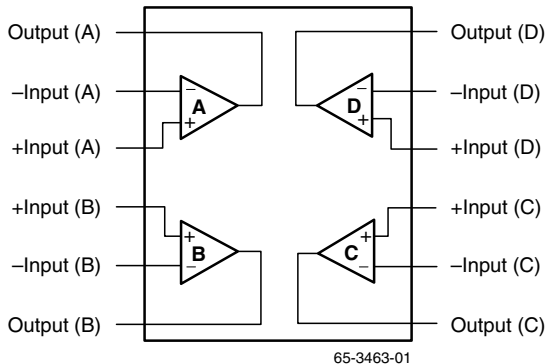
### Description

The RC4156 and RC4157 are monolithic integrated circuits, consisting of four independent high performance operational amplifiers constructed with an advanced epitaxial process.

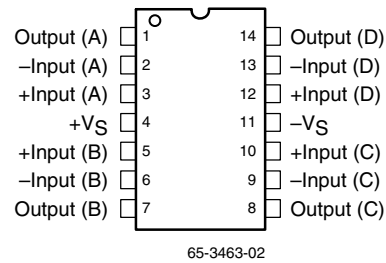
These amplifiers feature improved AC performance which far exceeds that of the 741 type amplifiers. Also featured are

excellent input characteristics and low noise, making this device the optimum choice for audio, active filter and instrumentation applications. The RC4157 is a decompensated version of the RC4156 and is AC stable in gain configurations of -5 or greater.

### Block Diagram



### Pin Assignments



## Absolute Maximum Ratings

(beyond which the device may be damaged)<sup>1</sup>

| Parameter                                  |               | Min        | Typ  | Max | Units |
|--|---------------|------------|------|-----|-------|
| Supply Voltage                             |               |            |      | ±20 | V     |
| Input Voltage <sup>2</sup>                 |               |            |      | ±15 | V     |
| Differential Input Voltage                 |               |            |      | 30  | V     |
| Output Short Circuit Duration <sup>3</sup> |               | Indefinite |      |     |       |
| PDTA < 50°C                                | SOIC          |            |      | 300 | mW    |
|  | PDIP          |            |      | 468 | mW    |
| Operating Temperature                      | RC4156/RC4157 | 0          |      | 70  | °C    |
| Storage Temperature                        |               | -65        |      | 150 | °C    |
| Junction Temperature                       | SOIC, PDIP    |            |      | 125 | °C    |
| Lead Soldering Temperature<br>(60 seconds) | DIP           |            |      | 300 | °C    |
|  | SOIC          |            |      | 260 | °C    |
| For T <sub>A</sub> > 50°C Derate at        | SOIC          |            | 5.0  |     | mW/°C |
|  | PDIP          |            | 6.25 |     | mW/°C |

### Notes:

- Functional operation under any of these conditions is NOT implied. Performance and reliability are guaranteed only if Operating Conditions are not exceeded.
- For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
- Short circuit to ground on one amplifier only.

## Operating Conditions

| Parameter       |                    | Min  | Typ | Max | Units |
|-----------------|--------------------|------|-----|-----|-------|
| θ <sub>JC</sub> | Thermal resistance |      | 60  |     | °C/W  |
| θ <sub>JA</sub> | Thermal resistance | SOIC | 200 |     | °C/W  |
|                 |                    | PDIP | 160 |     | °C/W  |

## Electrical Characteristics

(V<sub>S</sub> = ±15V, R<sub>C</sub> = 0°C ≤ T<sub>A</sub> ≤ +70°C)

| Parameters                         | Test Conditions                              | RC4156/4157 |     |     | Units |
|------------------------------------|--|-------------|-----|-----|-------|
|                                    |  | Min         | Typ | Max |       |
| Input Offset Voltage               | R <sub>S</sub> ≤ 10 kΩ                       |             |     | 6.5 | mV    |
| Input Offset Current               |  |             |     | 100 | nA    |
| Input Bias Current                 |  |             |     | 400 | nA    |
| Large Signal Voltage Gain          | R <sub>L</sub> ≥ 2 kΩ, V <sub>OUT</sub> ±10V | 15          |     |     | V/mV  |
| Output Voltage Swing               | R <sub>L</sub> ≥ 2 kΩ                        | ±10         |     |     | V     |
| Supply Current                     |  |             | 10  |     | mA    |
| Average Input Offset Voltage Drift |  |             | 5.0 |     | μV/°C |

## Electrical Characteristics

( $V_S = \pm 15V$  and  $T_A = +25^\circ C$  unless otherwise noted)

| Parameters                       | Test Conditions   | RC4156/4157 |          |     | Units                  |
|----------------------------------|---|-------------|----------|-----|------------------------|
|                                  |   | Min         | Typ      | Max |                        |
| Input Offset Voltage             | $R_S \leq 10\text{ k}\Omega$                                    |             | 1.0      | 5.0 | mV                     |
| Input Offset Current             |   |             | 30       | 50  | nA                     |
| Input Bias Current               |   |             | 60       | 300 | nA                     |
| Input Resistance                 |   |             | 0.5      |     | M $\Omega$             |
| Large Signal Voltage Gain        | $R_L \geq 2\text{ k}\Omega$ , $V_{OUT} \pm 10V$                 | 25          | 100      |     | V/mV                   |
| Output Voltage Swing             | $R_L \geq 10\text{ k}\Omega$                                    | $\pm 12$    | $\pm 14$ |     | V                      |
|                                  | $R_L \geq 2\text{ k}\Omega$                                     | $\pm 10$    | $\pm 13$ |     | V                      |
| Input Voltage Range              |   | $\pm 12$    | $\pm 14$ |     | V                      |
| Output Resistance                |   |             | 230      |     | $\Omega$               |
| Short Circuit Current            |   |             | 25       |     | mA                     |
| Common Mode Rejection Ratio      | $R_S \leq 10\text{ k}\Omega$                                    | 80          |          |     | dB                     |
| Power Supply Rejection Ratio     | $R_S \leq 10\text{ k}\Omega$                                    | 80          |          |     | dB                     |
| Supply Current (All Amplifiers)  | $R_L = \infty$  |             | 5.0      | 7.0 | mA                     |
| Transient Response (4156)        |   |             |          |     |                        |
| Rise Time                        |   |             | 60       |     | nS                     |
| Overshoot                        |   |             | 25       |     | %                      |
| Slew Rate                        |   | 1.3         | 1.6      |     | V/ $\mu$ S             |
| Unity Gain Bandwidth (4156)      |   | 2.8         | 3.5      |     | MHz                    |
| Phase Margin (4156)              | $R_L = 2\text{ k}\Omega$ , $C_L = 50\text{ pF}$                 |             | 50       |     | %                      |
| Transient Response (4157)        | $A_V = -5$  |             |          |     |                        |
| Rise Time                        |   |             | 50       |     | nS                     |
| Overshoot                        |   |             | 25       |     | %                      |
| Slew Rate                        |   | 6.5         | 8.0      |     | V/ $\mu$ S             |
| Unity Gain Bandwidth (4157)      | $A_V = -5$  | 15          | 19       |     | MHz                    |
| Phase Margin (4157)              | $A_V = -5$ , $R_L = 2\text{ k}\Omega$ ,<br>$C_L = 50\text{ pF}$ |             | 50       |     | %                      |
| Power Bandwidth                  | $V_{OUT} = 20V_{p-p}$   | 20          | 25       |     | kHz                    |
| Input Noise Voltage <sup>1</sup> | $F = 20\text{ Hz to } 20\text{ kHz}$                            |             | 1.4      | 5.0 | $\mu$ V <sub>RMS</sub> |
| Input Noise Current              | $F = 20\text{ Hz to } 20\text{ kHz}$                            |             | 15       |     | pA <sub>RMS</sub>      |
| Channel Separation               |   |             | 108      |     | dB                     |

**Note:**

1. Sample tested only.

### Typical Performance Characteristics

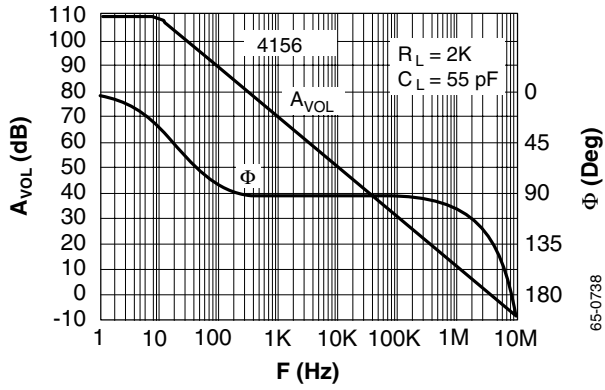


Figure 1. Open Loop Gain, Phase vs. Frequency

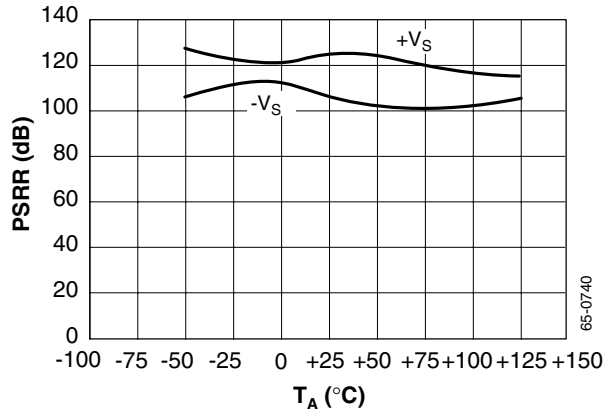


Figure 2. PSRR vs. Temperature

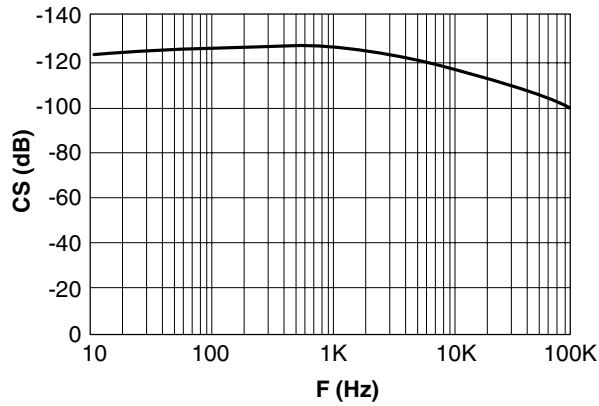
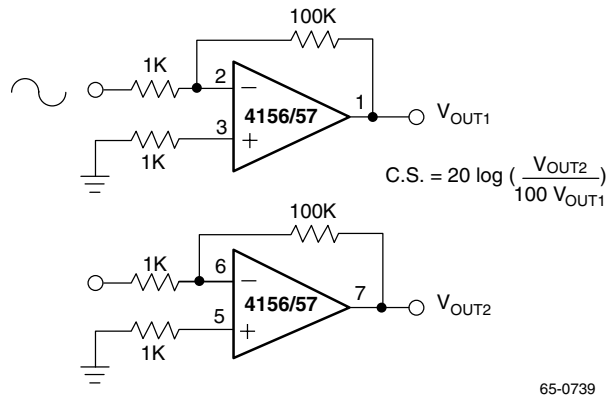


Figure 3. Channel Separation vs. Frequency



65-0739

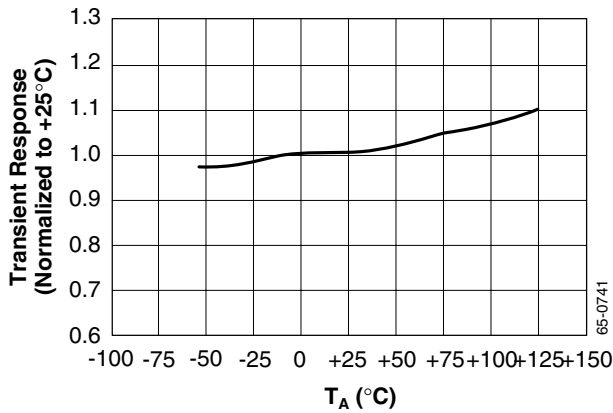


Figure 4. Transient Response vs. Temperature

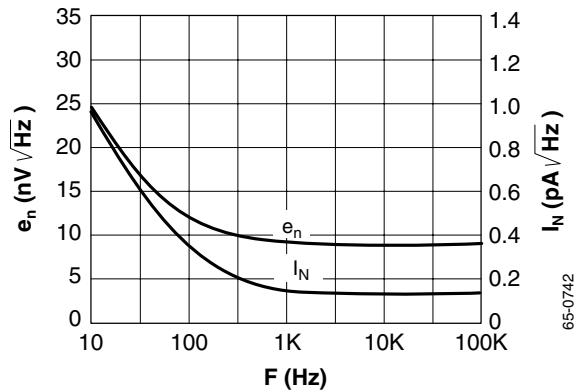


Figure 5. Input Noise Voltage, Current Density vs. Frequency

Typical Performance Characteristics (continued)

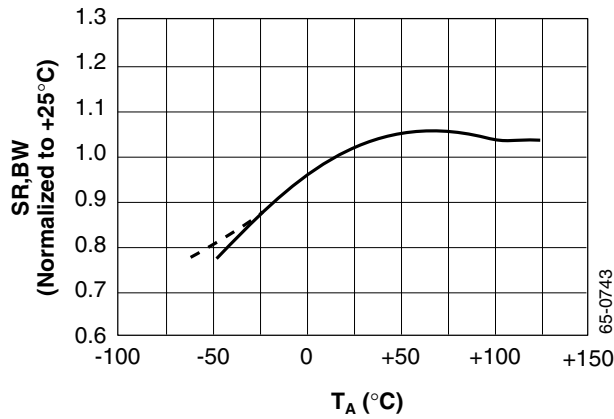


Figure 6. Slew Rate, Bandwidth vs. Temperature

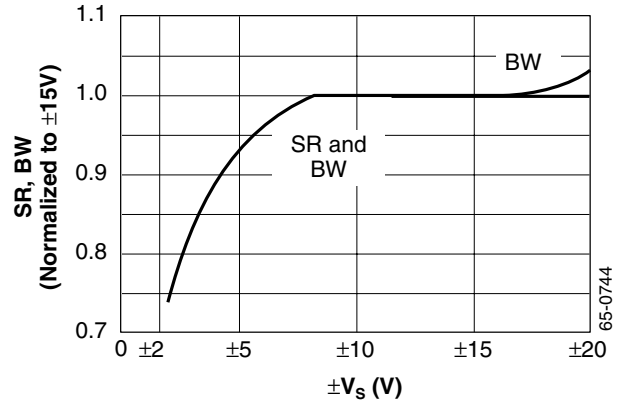


Figure 7. Slew Rate, Bandwidth vs. Supply Voltage

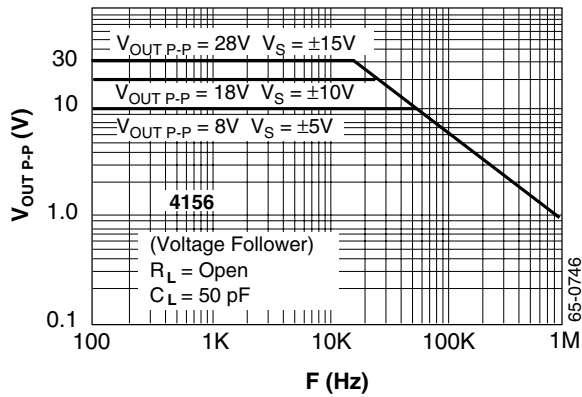


Figure 8. Output Voltage Swing vs. Frequency

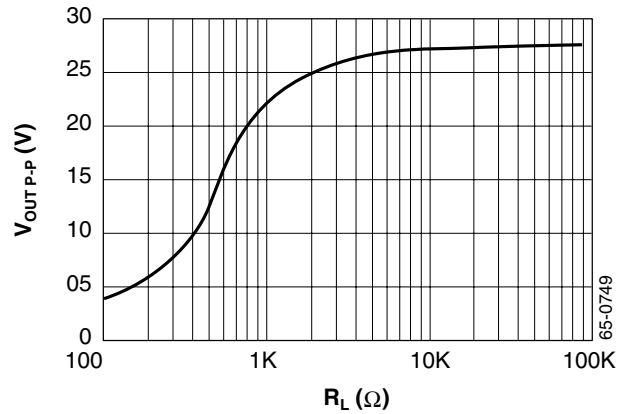


Figure 9. Output Voltage Swing vs. Load Resistance

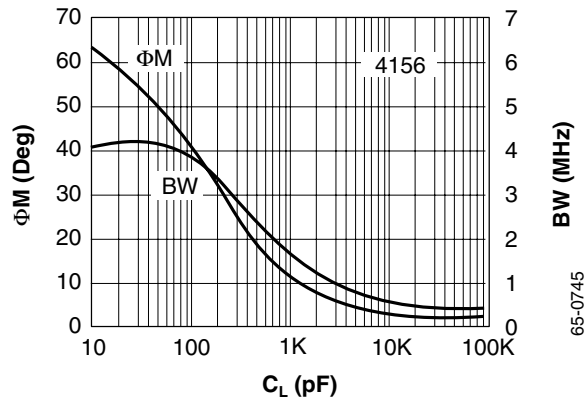
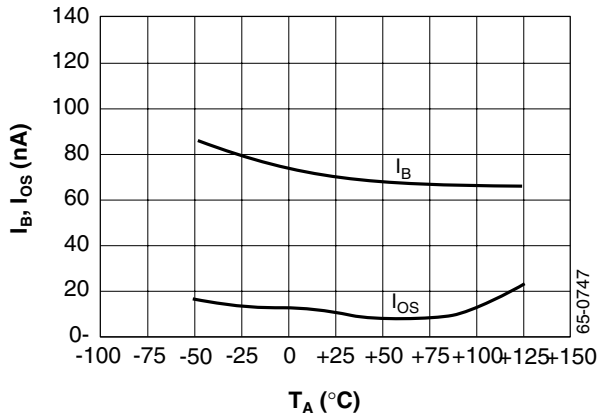
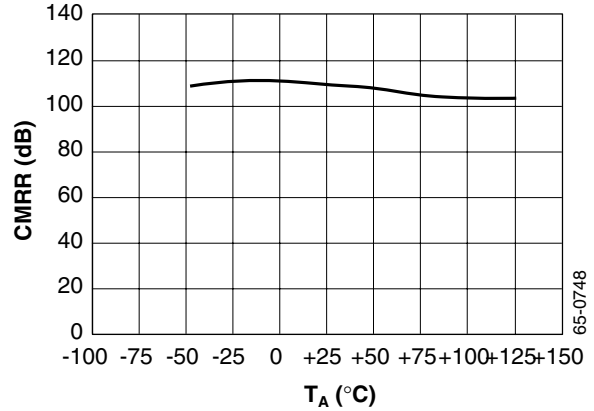


Figure 10. Small Signal Phase Margin, Unity Gain Bandwidth vs. Load Capacitance

**Typical Performance Characteristics** (continued)



**Figure 11. Input Bias, Offset Current vs. Temperature**



**Figure 12. CMRR vs. Temperature**

**Applications**

The RC4156 and RC4157 quad operational amplifiers can be used in almost any 741 application and will provide superior performance. The higher unity gain bandwidth and slew rate make it ideal for applications requiring good frequency response, such as active filter circuits, oscillators and audio amplifiers.

The following applications have been selected to illustrate the advantages of using the Fairchild Semiconductor RC4156 and RC4157 quad operational amplifiers.

**Triangle and Square Wave Generator**

The circuit of Figure 13 uses a positive feedback loop closed around a combined comparator and integrator. When power is applied the output of the comparator will switch to one of two states, to the maximum positive or maximum negative voltage. This applies a peak input signal to the integrator, and the integrator output will ramp either down or up, opposite of the input signal. When the integrator output (which is connected to the comparator input) reaches a threshold set by R1 and R2, the comparator will switch to the opposite polarity. This cycle will repeat endlessly, the integrator charging

positive then negative, and the comparator switching in a square wave fashion.

The amplitude of V<sub>2</sub> is adjusted by varying R1. For best operation, it is recommended that R1 and VR be set to obtain a triangle wave at V<sub>2</sub> with ±12V amplitude. This will then allow A3 and A4 to be used for independent adjustment of output-offset and amplitude over a wide range.

The triangle wave frequency is set by C0, R0, and the maximum output voltages of the comparator. A more symmetrical waveform can be generated by adding a back-to-back Zener diode pair as shown in Figure 14.

An asymmetric triangle wave is needed in some applications. Adding diodes as shown by the dashed lines is a way to vary the positive and negative slopes independently.

The frequency range can be very wide and the circuit will function well up to about 10 kHz. The square wave transition time at V<sub>1</sub> is less than 21 μs when using the RC4156.

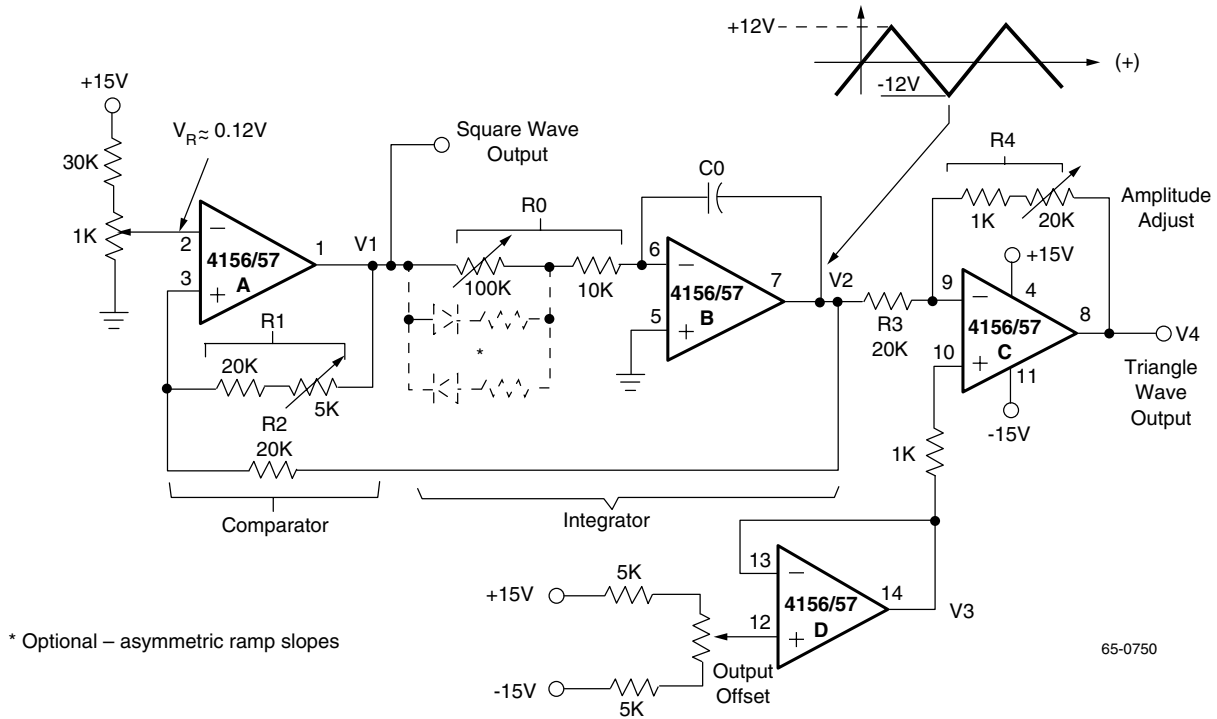


Figure 13. Triangle and Square Wave Generator

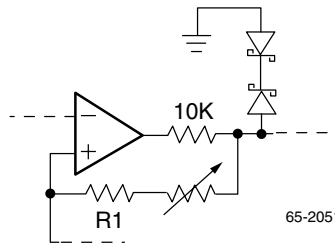


Figure 14. Triangle Generator—Symmetrical Output Option

### Active Filters

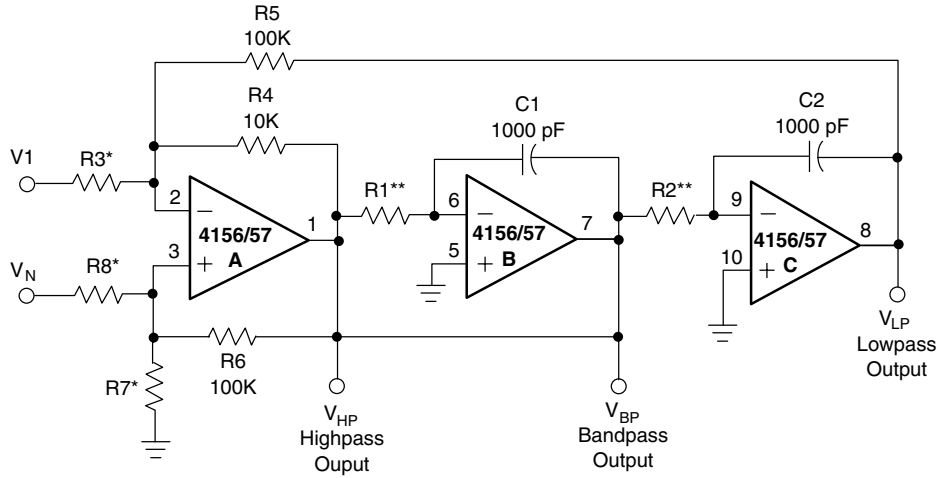
The introduction of low-cost quad op amps has had a strong impact on active filter design. The complex multiple-feedback, single op amp filter circuits have been rendered obsolete for most applications. State-variable active-filter circuits using three to four op amps per section offer many advantages over the single op amp circuits. They are relatively insensitive to the passive-component tolerances and variations. The Q, gain, and natural frequency can be independently adjusted. Hybrid construction is very practical because resistor and capacitor values are relatively low and the filter parameters are determined by resistance ratios rather than by single resistors. A generalized circuit diagram of the 2-pole state-variable active filter is shown in Figure 15. The particular input connections and component-values can be calculated for specific applications. An important feature of the state-variable filter is that it can be inverting or non-inverting and can simultaneously provide three outputs:

lowpass, bandpass, and highpass. A notch filter can be realized by adding one summing op amp.

The RC4156 was designed and characterized for use in active filter circuits. Frequency response is fully specified with minimum values for unity-gain bandwidth, slew-rate, and full-power response. Maximum noise is specified.

Output swing is excellent with no distortion or clipping. The RC4156 provides full, undistorted response up to 20 kHz and is ideal for use in high-performance audio and telecommunication equipment.

In the state-variable filter circuit, one amplifier performs a summing function and the other two act as integrators. The choice of passive component values is arbitrary, but must be consistent with the amplifier operating range and input signal



\* Input connections are chosen for inverting or non-inverting response. Values of R3,R7,R8 determine gain and Q.  
 \*\* Values of R1 and R2 determine natural frequency.

65-0751

**Figure 15. 2-Pole State-Variable Active Filter**

characteristics. The values shown for C1, C2, R4, R5 and R6 are arbitrary. Pre-selecting their values will simplify the filter tuning procedures, but other values can be used if necessary.

The generalized transfer function for the state-variable active filter is:

$$T(s) = \frac{a_2s^2 + a_1s + a_0}{s^2 + b_1s + b_0}$$

Filter response is conventionally described in terms of a natural frequency  $\omega_0$  in radians/sec, and Q, the quality of the complex pole pair. The filter parameters  $\omega_0$  and Q relate to the coefficients in T(s) as:

$$\omega_0 = \sqrt{b_0} \text{ and } Q = \frac{\omega_0}{b_1}$$

The input configuration determines the polarity (inverting or non-inverting), and the output selection determines the type of filter response (lowpass, bandpass, or highpass).

Notch and all-pass configurations can be implemented by adding another summing amplifier.

Bandpass filters are of particular importance in audio and telecommunication equipment. A design approach to band-pass filters will be shown as an example of the state-variable configuration.

**Design Example Bandpass Filter**

For the bandpass active filter (Figure 16) the input signal is applied through R3 to the inverting input of the summing amplifier and the output is taken from the first integrator (VBP). The summing amplifier will maintain equal voltage at the inverting and non-inverting inputs (see Equation 1).

$$\frac{R3R5}{R4 + \frac{R3R5}{R3 + R5}} V_{HP}(s) + \frac{R3R4}{R5 + \frac{R3R4}{R3 + R4}} V_{LP}(s) + \frac{R4R5}{R3 + \frac{R4R5}{R4 + R5}} V_{IN}(s) + \frac{R7}{R6 + R7} V_{BP}(s)$$

**Equation 1.**



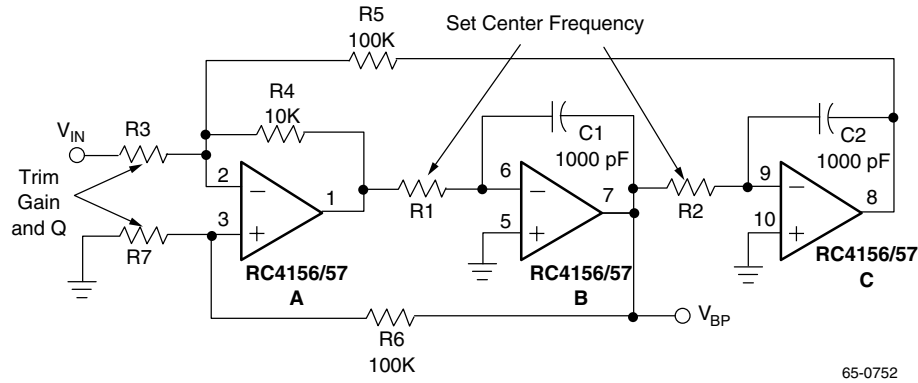


Figure 16. Bandpass Active Filter

These equations can be combined to obtain the transfer function:

$$V_{BP}(s) = -\frac{1}{R1C1S}V_{HP}(s) \quad \text{and} \quad V_{LP}(s) = -\frac{1}{R2C2S}V_{BP}(s)$$

$$\frac{V_{BP}(s)}{V_{IN}(s)} = \frac{\frac{R4}{R3} \cdot \frac{1}{R1C1} S}{S^2 + \frac{R7}{R6 + R7} \left(1 + \frac{R4}{R5} + \frac{R4}{R3}\right) \left(\frac{1}{R1C1}\right) S + \left(\frac{R4}{R5}\right) \left(\frac{1}{R1C1R2C2}\right)}$$

Defining  $1/R1C1$  as  $\omega_1$ ,  $1/R2C2$  as  $\omega_2$ , and substituting in the assigned values for  $R4$ ,  $R5$ , and  $R6$ , then the transfer function simplifies to:

$$\frac{V_{BP}(s)}{V_{IN}(s)} = \frac{\frac{10^4}{R3} \cdot \omega_1 s}{S^2 + \left[ \frac{1.1 + \frac{10^4}{R3}}{1 + \frac{10^5}{R7}} \right] \omega_1 s + \frac{1}{\omega_1 \omega_2}}$$

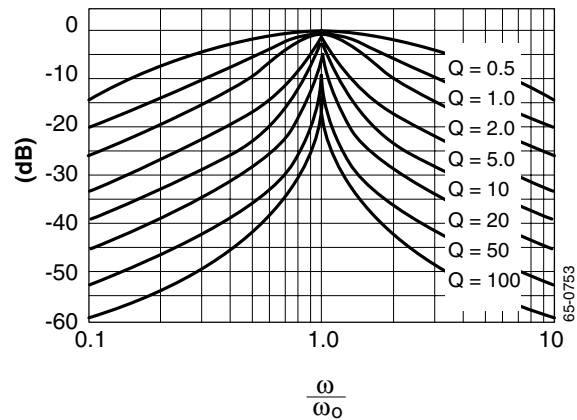
This is now in a convenient form to look at the center-frequency  $\omega_0$  and filter  $Q$ .

$$\omega_0 = \sqrt{0.1 \omega_1 \omega_2}$$

$$\omega_0 = 10^{-9} \sqrt{0.1 R1 R2} \quad \text{and}$$

$$Q = \left[ \frac{1 + \frac{10^5}{R7}}{1.1 + \frac{10^4}{R3}} \right] \omega_0$$

The frequency responses for various values of  $Q$  are shown in Figure 17.



$$\frac{V_{BP}}{V_{IN}} = \frac{\frac{\omega}{\omega_0} \frac{1}{Q}}{\sqrt{\left[1 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2 + \left(\frac{1}{Q} \frac{\omega}{\omega_0}\right)^2}}$$

Figure 17. Bandpass Transfer Characteristics Normalized for Unity Gain and Frequency



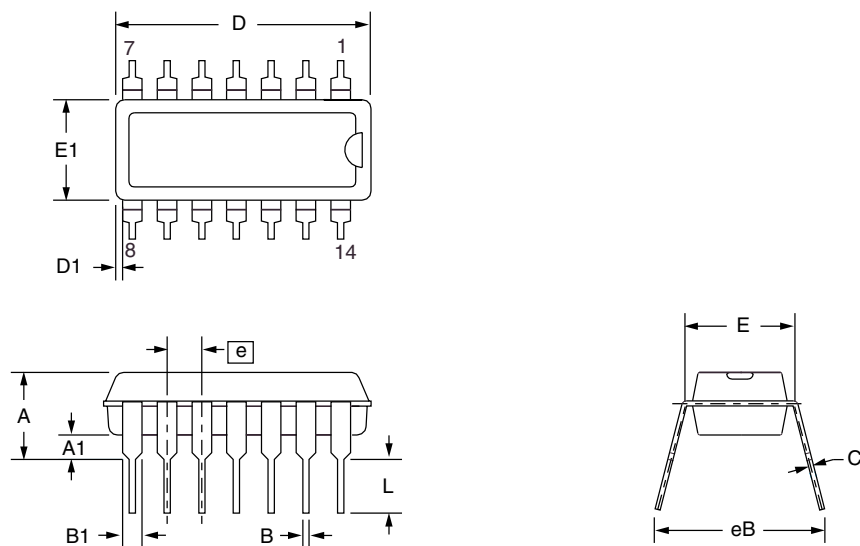
## Mechanical Dimensions (continued)

### 14-Lead Plastic DIP Package

| Symbol | Inches   |      | Millimeters |       | Notes |
|--------|----------|------|-------------|-------|-------|
|        | Min.     | Max. | Min.        | Max.  |       |
| A      | —        | .210 | —           | 5.33  |       |
| A1     | .015     | —    | .38         | —     |       |
| A2     | .115     | .195 | 2.93        | 4.95  |       |
| B      | .014     | .022 | .36         | .56   |       |
| B1     | .045     | .070 | 1.14        | 1.78  |       |
| C      | .008     | .015 | .20         | .38   | 4     |
| D      | .725     | .795 | 18.42       | 20.19 | 2     |
| D1     | .005     | —    | .13         | —     |       |
| E      | .300     | .325 | 7.62        | 8.26  |       |
| E1     | .240     | .280 | 6.10        | 7.11  | 2     |
| e      | .100 BSC |      | 2.54 BSC    |       |       |
| eB     | —        | .430 | —           | 10.92 |       |
| L      | .115     | .200 | 2.92        | 5.08  |       |
| N      | 14       |      | 14          |       | 5     |

#### Notes:

1. Dimensioning and tolerancing per ANSI Y14.5M-1982.
2. "D" and "E1" do not include mold flashing. Mold flash or protrusions shall not exceed .010 inch (0.25mm).
3. Terminal numbers are shown for reference only.
4. "C" dimension does not include solder finish thickness.
5. Symbol "N" is the maximum number of terminals.



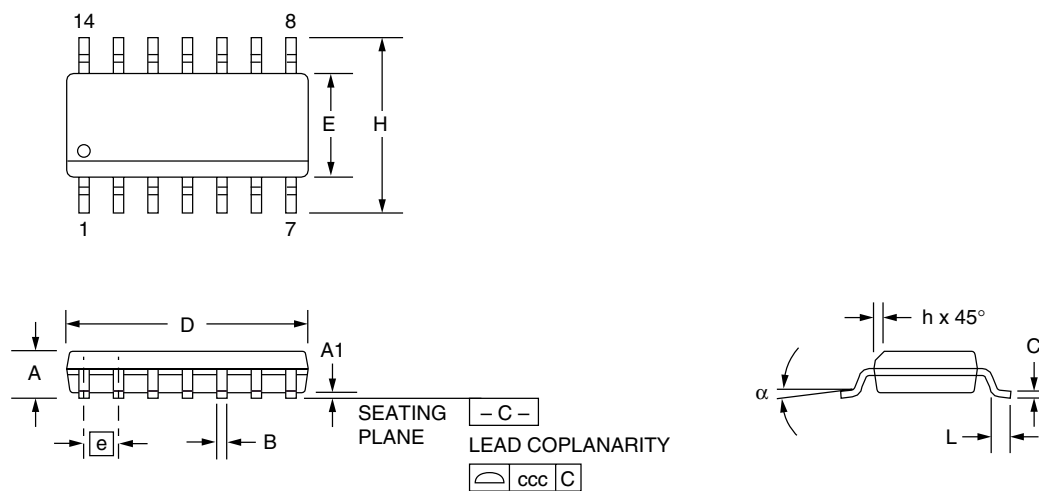
# Mechanical Dimensions (continued)

## 14-Lead SOIC Package

| Symbol   | Inches   |      | Millimeters |      | Notes |
|----------|----------|------|-------------|------|-------|
|          | Min.     | Max. | Min.        | Max. |       |
| A        | .053     | .069 | 1.35        | 1.75 |       |
| A1       | .004     | .010 | 0.10        | 0.25 |       |
| B        | .013     | .020 | 0.33        | 0.51 |       |
| C        | .008     | .010 | 0.19        | 0.25 | 5     |
| D        | .336     | .345 | 8.54        | 8.76 | 2     |
| E        | .150     | .158 | 3.81        | 4.01 | 2     |
| e        | .050 BSC |      | 1.27 BSC    |      |       |
| H        | .228     | .244 | 5.79        | 6.20 |       |
| h        | .010     | .020 | 0.25        | 0.50 |       |
| L        | .016     | .050 | 0.40        | 1.27 | 3     |
| N        | 14       |      | 14          |      | 6     |
| $\alpha$ | 0°       | 8°   | 0°          | 8°   |       |
| ccc      | —        | .004 | —           | 0.10 |       |

**Notes:**

1. Dimensioning and tolerancing per ANSI Y14.5M-1982.
2. "D" and "E" do not include mold flash. Mold flash or protrusions shall not exceed .010 inch (0.25mm).
3. "L" is the length of terminal for soldering to a substrate.
4. Terminal numbers are shown for reference only.
5. "C" dimension does not include solder finish thickness.
6. Symbol "N" is the maximum number of terminals.



## Ordering Information

| Product Number | Temperature Range | Screening  | Package            | Package Marking |
|----------------|-------------------|------------|--------------------|-----------------|
| RC4156N        | 0° to 70°C        | Commercial | 14 Pin Plastic DIP | RC4156N         |
| RC4157N        | 0° to 70°C        | Commercial | 14 Pin Plastic DIP | RC4157N         |
| RC4156M        | 0° to 70°C        | Commercial | 14 Pin Wide SOIC   | RC4156M         |
| RC4157M        | 0° to 70°C        | Commercial | 14 Pin Wide SOIC   | RC4157M         |

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2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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| Product  | Product status  | Pricing* | Package type        | Leads | Package marking      | Packing method |
|----------|-----------------|----------|---------------------|-------|----------------------|----------------|
| RC4157M  | Full Production | \$1.17   | SOIC                | 14    | \$Y&Z&2&T<br>RC4157M | RAIL           |
| RC4157MT | Full Production | \$1.17   | SOIC                | 14    | \$Y&Z&2&T<br>RC4157M | TAPE REEL      |
| RC4157N  | Full Production | \$1.14   | <a href="#">DIP</a> | 14    | \$Y&Z&4&T<br>RC4157N | RAIL           |

\* 1,000 piece Budgetary Pricing

[back to top](#)

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find products

[Home](#) >> [Find products](#) >>

[Products groups](#)

[Analog and Mixed](#)

[Signal](#)

[Discrete](#)

[Interface](#)

[Logic](#)

[Microcontrollers](#)

[Non-Volatile](#)

[Memory](#)

[Optoelectronics](#)

[Markets and](#)

[applications](#)

[New products](#)

[Product selection and](#)

[parametric search](#)

[Cross-reference](#)

[search](#)

RC4156  
High Performance Quad Operational  
Amplifiers

Contents

[Product status/pricing/packaging](#)

Datasheet

[Download this](#)

[datasheet](#)

PDF

[e-mail this datasheet](#)

[E-]

This page

[Print version](#)

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[Dotted line](#)

[Product Change Notices](#)

[\(PCNs\)](#)

[Dotted line](#)

[Support](#)

[Dotted line](#)

[Distributor and field sales](#)

[representatives](#)

[Dotted line](#)

[Quality and reliability](#)

[Dotted line](#)

[Design tools](#)

[Product status/pricing/packaging](#)

| Product  | Product status  | Pricing* | Package type        | Leads | Package marking      | Packing method |
|----------|-----------------|----------|---------------------|-------|----------------------|----------------|
| RC4156N  | Full Production | \$0.74   | <a href="#">DIP</a> | 14    | \$Y&Z&4&T<br>RC4156N | RAIL           |
| RC4156M  | Full Production | \$0.77   | SOIC                | 14    | \$Y&Z&2&T<br>RC4156M | RAIL           |
| RC4156MT | Full Production | \$0.84   | SOIC                | 14    | \$Y&Z&2&T<br>RC4156M | TAPE REEL      |

\* 1,000 piece Budgetary Pricing

[back to top](#)

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