4156 Quad High Performance Operational Amplifier

DESCRIPTION

The RM4156/RC4156 is a monolithic integrated circuit, consisting of four independent high performance operational amplifiers constructed with the planar epitaxial process.

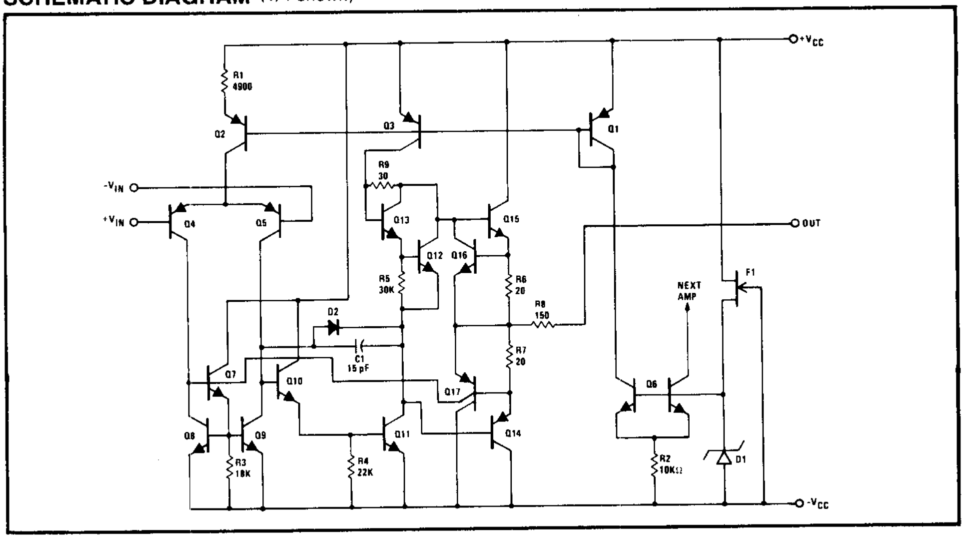
These amplifiers feature guaranteed A.C. performance which far exceeds that of the 741 type amplifiers. Also featured are excellent input characteristics and guaranteed low noise making this device the optimum choice for audio, active filter and instrumentation applications.

FEATURES

	Typical	Guaranteed
• Unity Gain Bandwidth	3.5 MHz	2.8 MHz
• High Slew Rate	1.6V/μS	1.3V/μS
• Low Noise Voltage	1.4μV	2.0μV RMS

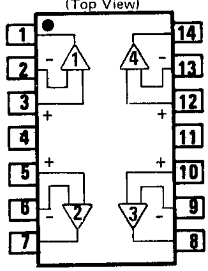
- Indefinite Short Circuit Protection
- No Crossover Distortion
- Low Input Offset and Bias Parameters
- Internal Compensation

SCHEMATIC DIAGRAM (1/4 Shown)



CONNECTION INFORMATION

DB and DC
Dual In-line Packages
(Top View)



PIN	FUNCTION
1	OUTPUT A
2	$-V_{IN}$ A
3	$+V_{IN}$ A
4	V+
5	$+V_{IN}$ B
6	$-V_{IN}$ B
7	OUTPUT B
8	OUTPUT C
9	$-V_{IN}$ C
10	$+V_{IN}$ C
11	V-
12	$+V_{IN}$ D
13	$-V_{IN}$ D
14	OUTPUT D

Order Part Nos.
RM4156DC, RV4156DB, RV4156DC, RC4156DC, RC4156DB

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±20V
Internal Power Dissipation (Note 1)	880 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short Circuit Duration (Note 3)	Indefinite

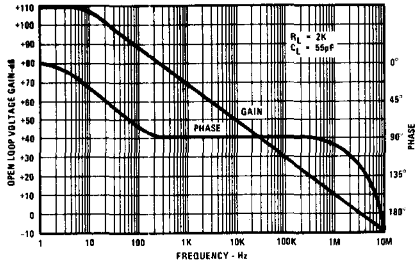
Storage Temperature Range		-65 to +150°C
Operating Temperature Range	RM4156	-55 to +125°C
	RV4156	-40 to +85°C
	RC4156	0 to +70°C
Lead Soldering Temperature (60 sec)		300°C

ELECTRICAL CHARACTERISTICS V_{CC} ±15V T_A +25°C unless otherwise specified

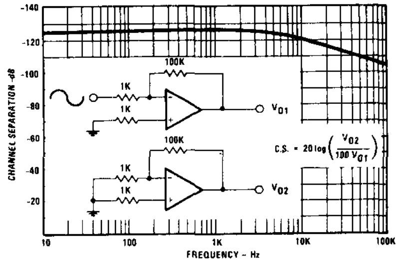
PARAMETER	CONDITIONS	RM4156 MIN	RM4156 TYP	RM4156 MAX	RV4156/RC4156 MIN	RV4156/RC4156 TYP	RV4156/RC4156 MAX	UNITS
Input Offset Voltage	$R_S \leq 10$ KΩ		0.5	3.0		1.0	5.0	mV
Input Offset Current			15	30		30	50	nA
Input Bias Current			60	200		60	300	nA
Input Resistance			0.5			0.5		MΩ
Large Signal Voltage Gain	$R_L \geq 2$ KΩ V_{OUT} ±10V	50,000	100,000		25,000	100,000		V/V
Output Voltage Swing	$R_L \geq 10$ KΩ	±12	±14		±12	±14		V
	$R_L \geq 2$ KΩ	±10	±13		±10	±13		V
Input Voltage Range		±12	±14		±12	±14		V
Output Resistance			230			230		Ω
Output Short Circuit Current			25			25		mA
Common Mode Rejection Ratio	$R_S \leq 10$ KΩ	80			80			dB
Power Supply Rejection Ratio	$R_S \leq 10$ KΩ	80			80			dB
Supply Current (all amplifiers)	$R_L = \infty$		4.5	5.0		5.0	7.0	mA
Transient Response								
Rise Time			50			75		ns
Overshoot			25%			25%		%
Slew Rate		1.3	1.6		1.3	1.6		V/µs
Unity Gain Bandwidth		2.8	3.5		2.8	3.5		MHz
Phase Margin	R_L = 2 KΩ R_C = 50 pF		50			50		degrees
Full Power Bandwidth	V_O = 20V p-p	20	25		20	25		kHz
Input Noise Voltage	f = 20 Hz to 20 kHz		1.4	2.0		1.4	2.0	µV RMS
Input Noise Current	f = 20 Hz to 20 kHz		15			15		pA RMS
Channel Separation			-108			-108		dB
The following specifications apply for -55°C ≤ T_A ≤ +125°C for RM4156, -40°C ≤ T_A ≤ +85°C for RV4156, 0°C ≤ T_A ≤ +70°C for RC4156.								
Input Offset Voltage	$R_S \leq 10$ KΩ			5.0			6.5	mV
Input Offset Current				75			100	nA
Input Bias Current				325			400	nA
Large Signal Voltage Gain	$R_L \geq 2$ KΩ V_{OUT} ±10V	25,000			15,000			V/V
Output Voltage Swing	$R_L \geq 2$ KΩ	±10			±10			V
Supply Current			10			10		mA
Average Offset Voltage Drift			5			5		µV/°C

Notes:
1. Rating applies for case temperature of +25°C maximum; derate linearity at 6.4 mW/°C for temperatures above +25°C.
2. For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
3. Short circuit to ground on one amplifier only.

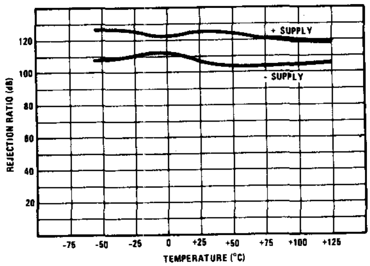
TYPICAL PERFORMANCE DATA



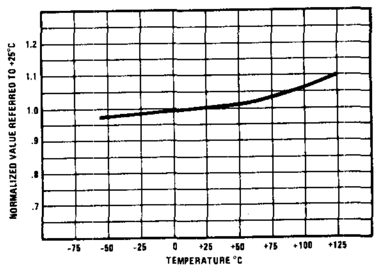
Open Loop Frequency Response



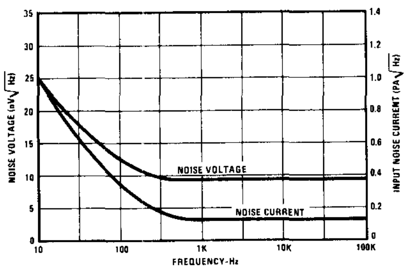
Channel Separation vs. Frequency



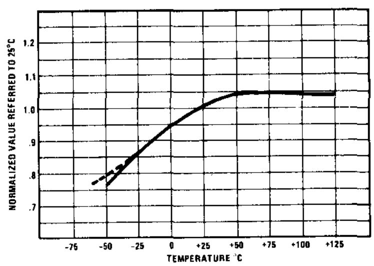
Power Supply Rejection Ratio vs. Temperature



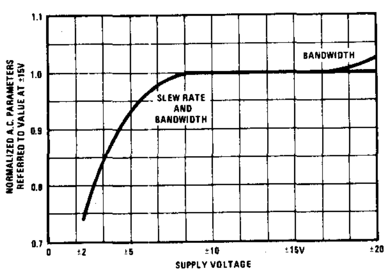
Transient Response vs. Temperature



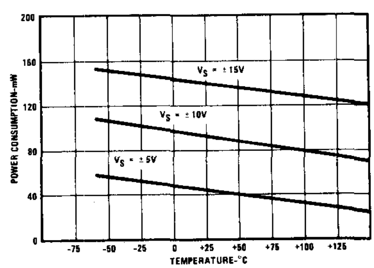
Input Noise vs. Frequency



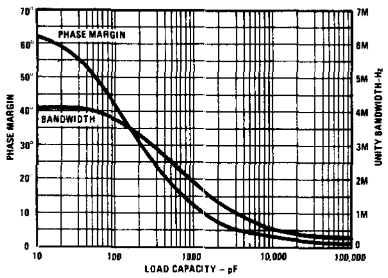
Normalized AC Parameters vs. Temperature



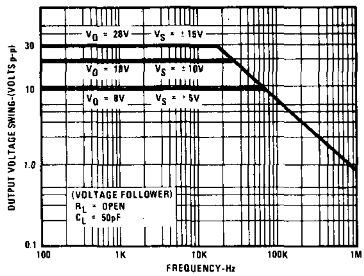
Slew Rate vs. Supply Voltage



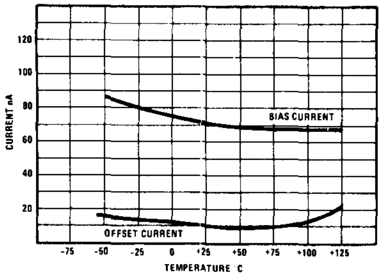
Power Consumption vs. Temperature



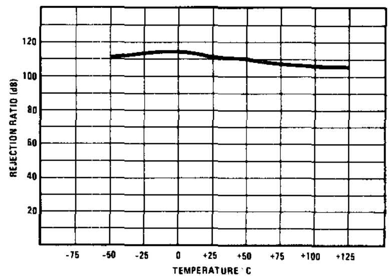
Small Signal Bandwidth and Phase Margin vs. Load Capacitance



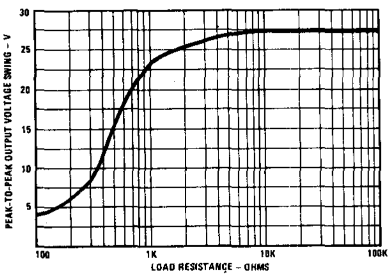
Output Voltage Swing vs. Frequency



Input Currents vs. Temperature



Common Mode Rejection Ratio vs. Temperature



Output Voltage Swing vs. Load Resistance

AVAILABLE TYPES

Part Number	Package	Operating Temperature
RM4156DC	Ceramic	-55 to +125°C
RV4156DB	Plastic	-40 to +85°C
RV4156DC	Ceramic	-40 to +85°C
RC4156DC	Ceramic	0 to +70°C
RC4156DB	Plastic	0 to +70°C

HIGH RELIABILITY OPTIONS

Part Type	Added Screening	Order Part No.
RM4156DC	With MIL-STD-883 Class B processing	RM4156DC3
RV4156DC RC4156DC	With A+3 processing* including burn-in and tightened AQL	RV4156DC3 RC4156DC3
RV4156DB RC4156DB	With A+2 processing* including "Hot Rail" testing, burn-in, temp cycle and tightened AQL	RV4156DB2 RC4156DB2
	With A+1 processing* including "Hot Rail" testing, temp cycle and tightened AQL	RV4156DB1 RC4156DB1

* Full description contained in the A+ bulletin available at your local Raytheon Sales Office.

APPLICATIONS

The 4156 Quad Operational Amplifier 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 Raytheon 4156 Quad Operational Amplifier.

VERSATILE TRIANGLE-AND-SQUARE WAVE GENERATOR

This circuit generates a precise triangle-wave with independently adjustable frequency, offset, and amplitude. A square-wave is also available from a separate output. The circuit exhibits excellent stability in both amplitude and frequency when using the 4156 quad op amp. See Figure 1.

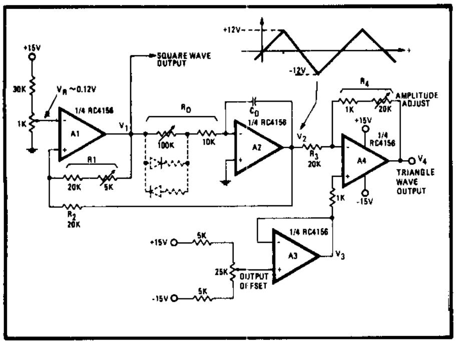


Figure 1. Triangle-and-Square Wave Generator

Amplifier A1 acts as a comparator and will swing between the positive and negative limits, typically +14V and -13.5V. The square-wave from amplifier A1 is converted to a triangle-wave by amplifier A2. Amplitude of V_2 is adjusted by varying R_1. For best operation, it is recommended that R_1 and V_R be set to obtain a triangle-wave at V_2 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 output frequency can be easily calculated. The switching transitions occur at:

$$\frac{R_1}{R_1 + R_2} V_2 + \frac{R_2}{R_1 + R_2} V_{1H} = V_R$$

and

$$\frac{R_1}{R_1 + R_2} V_2 + \frac{R_2}{R_1 + R_2} V_{1L} = V_R$$

where V_{1H} is the positive saturation level and V_{1L} is the negative saturation level. For a ±12V triangle-wave at output of A2, V_R will need to be approximately 0.12V and $R_2/R_1 = 1.87$.

Amplifiers A3 and A4 are used to independently adjust output offset and amplitude. The output V_4 will be:

$$V_4 = -\frac{R_4}{R_3} V_2 + V_3$$

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.

Frequency range can be very wide and the circuit will function very well up to about 10 kHz. Transition time for the square-wave at V_1 is less than 21 μsec when using the 4156.

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 2. 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 noninverting and can simultaneously provide three outputs: lowpass, bandpass, and highpass. A notch filter can be realized by adding one summing op amp.

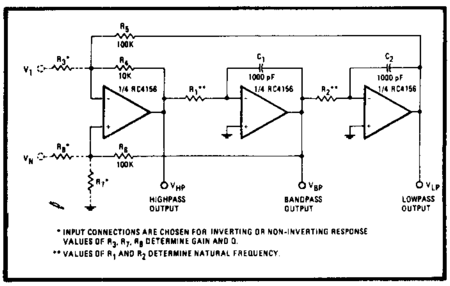


Figure 2. Generalized State-Variable Configuration for Active Filter

The Raytheon 4156 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 Raytheon 4156 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 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:

$$T(s) = \frac{a_2 s^2 + a_1 s + a_0}{s^2 + b_1 s + b_0}$$

Filter response is conventionally described in terms of a natural frequency ω_0 in radians/sec, and Q, the quality of the complex pole pair. The filter parameters ω_0 and Q relate to the coefficients in T(s) as:

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

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

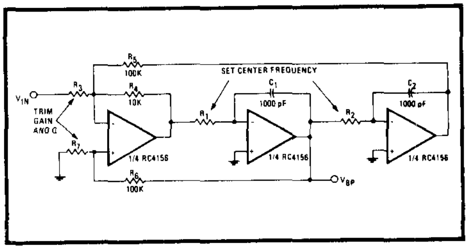


Figure 3. Bandpass Active Filter

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 bandpass filters will be shown as an example of the state-variable configuration.

DESIGN EXAMPLE – BANDPASS FILTER

In this example, the input signal is applied through R_3 to the inverting input of the summing amplifier and the output is taken from the first integrator (V_{BP}). The summing amplifier will maintain equal voltage at the inverting and noninverting inputs, (see equation below).

$$\frac{\dfrac{R_3R_5}{R_3+R_5}}{R_4 + \dfrac{R_3R_5}{R_3+R_5}} V_{HP}(s) + \frac{\dfrac{R_3R_4}{R_3+R_4}}{R_5 + \dfrac{R_3R_4}{R_3+R_4}} V_{LP}(s) + \frac{\dfrac{R_4R_5}{R_4+R_5}}{R_3 + \dfrac{R_4R_5}{R_4+R_5}} V_{in}(s) = \frac{R_7}{R_6+R_7} V_{BP}(s)$$

These equations can be combined to obtain the transfer function:

$$V_{BP}(s) = -\frac{1}{R_1C_1S} V_{HP}(s) \quad \text{and} \quad V_{LP}(s) = -\frac{1}{R_2C_2S} V_{BP}(s)$$

$$\frac{V_{BP}(s)}{V_{in}(s)} = \frac{\dfrac{R_4}{R_3}\dfrac{1}{R_1C_1} s}{s^2 + \dfrac{R_7}{R_6+R_7}\left(1 + \dfrac{R_4}{R_5} + \dfrac{R_4}{R_3}\right)\left(\dfrac{1}{R_1C_1}\right)s + \dfrac{R_4}{R_5}\dfrac{1}{R_1C_1R_2C_2}}$$

RAYTHEON

Defining $1/R_1C_1$ as ω_1, $1/R_2C_2$ as ω_2, and substituting in the assigned values for R_4, R_5, and R_6, then the transfer function simplifies to:

$$\frac{V_{BP}(s)}{V_{in}(s)} = \frac{\frac{10^4}{R_3}\,\omega_1 s}{s^2 + \left[\frac{1.1 + \frac{10^4}{R_3}}{1 + \frac{10^5}{R_7}}\right]\omega_1 s + \frac{0.1}{\omega_1\omega_2}}$$

This is now in a convenient form to look at the center-frequency ω_0 and filter Q.

$$\omega_0 = \sqrt{0.1\,\omega_1\omega_2} = 10^{-9}\sqrt{0.1\,R_1R_2} \quad \text{and} \quad Q = \left[\frac{1 + \frac{10^5}{R_7}}{1.1 + \frac{10^4}{R_3}}\right]\omega_0$$

The frequency response for various values of Q are shown in Figure 4.

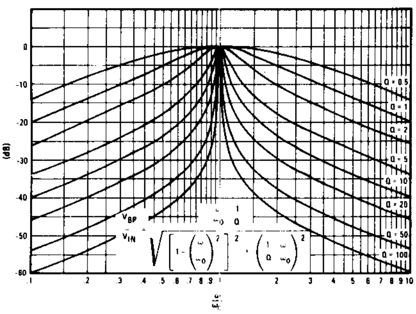


Figure 4. Bandpass Transfer Characteristics Normalized for Unity Gain and Frequency

These equations suggest a tuning sequence where ω_0 is first trimmed via R_1 or R_2, then Q is trimmed by varying R_7 and/or R_3. An important advantage of the state-variable bandpass filter is that Q can be varied without affecting center frequency ω_0.

This analysis has assumed ideal op amps operating within their linear range, which is a valid design approach for a reasonable range of ω_0 and Q. At extremes of ω_0 and at high values of Q, the op amp parameters become significant. A rigorous analysis is very complex, but some factors are particularly important in designing active filters:

1. The passive component values should be chosen such that all op amps are operating within their linear region for the anticipated range of input signals. Slew rate, output current rating, and common-mode input range must be considered. For the integrators, the current through the feedback capacitor (I = C dV/dt) should be included in the output current computations.

2. From the equation for Q, it would seem that infinite Q could be obtained by making R_7 zero. But as R_7 is made small, the Q becomes limited by the op amp gain at the frequency of interest. The effective closed-loop gain is being increased directly as R_7 is made smaller, and the ratio of open-loop gain to closed-loop gain is becoming less. The gain and phase error of the filter at high Q is very dependent on the op-amp open-loop gain at ω_0.

3. The attenuation at extremes of frequency is limited by the op amp gain and unity-gain bandwidth. For integrators, the finite open-loop op-amp gain limits the accuracy at the low-end. The open-loop roll-off of gain limits the filter attenuation at high frequency.

The Raytheon 4156 Quad Operational Amplifier has much better frequency response than a conventional 741 circuit and is ideal for active filter use. Natural frequencies of up to 10 kHz are readily achieved and up to 20 kHz is practical for some configurations. Q can range up to 50 with very good accuracy and up to 500 with reasonable response. The extra gain of the 4156 at high frequencies gives the Raytheon quad op amp an extra margin of performance in active-filter circuits.

	SYMBOL	RM/RV/RC4156[2]			LM149/249/349 LM148/248/348			HA4741-2/5			RM/RV/RC4157			UNIT
Maximum Ratings Supply Voltage Range	V_{CC}	±4 to ±20			±4 to ±22			±4 to ±20			±4 to ±20			V
Differential Input Voltage	V_{ID}	±30			±44/±36*			±30			±30			V
Input Voltage		±15			±22/±18*			±15			±15			V
Power Dissipation	P_D	880			900			800			880			mW
Electrical Characteristics	**@25°C**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	
Test Condition V_{CC}:			±15			±15			±15			±15		V
Input Offset Voltage	V_{IO}		0.5 1.0	3.0 5.0*		1.0	5.0 6.0*		0.5 1.0	3.0 5.0*		0.5 1.0	3.0 5.0*	mV
Input Offset Current	I_{IO}		15 30	30 50*		4	25 50*		15 30	30 50*		15 30	30 50*	nA
Input Bias Current	I_{IB}		60	200 300*		30	100 200*		60	200 300*		60	200 300*	nA
Input Common Mode Voltage Range	V_{ICR}	±12	±14		±12**			±12			±12			V
Supply Current	I_D		4.5/5	5/7*		2.4	3.6		4.5/5	5/7*		4.5/5	5/7*	mA
Open Loop Voltage Gain	A_{VOL}	50 25*	100		50 25*	160		50 25*	100 50*		50 25*	100		V/mV
Output Voltage Swing	V_{OR}	±12	±14		±12**	±13					±12			V
Common Mode Rejection Ratio	CMRR	80			70**	90		80			80			dB
Power Supply Rejection Ratio	PSRR	80dB			77** dB	96		80** dB			80 dB			
Unity Gain Bandwidth	BW	2.8	3.5			1.0/ 4.0†(1)			3.5		15(1)			MHz
Slew Rate	SR	1.3	1.6			0.5/ 2.0†			1.6		6.5	8		V/μs
Output Sink Current	I_{sink}							5	15					mA
Output Source Current	I_{source}							5	15					mA
Channel Separation			−108			−120			−108			−108		dB
Operating Temperature Range		−55 −40 0	RM RV RC	+125 85 70	−55 −25 0	148 248 348	+125 +85 +70	−55 0	−2 −5	+125 70	−55 −25 0	RM RV RC	+125 +85 +70	°C
Package: 14 pin Dip	Hermetic	DC			DC			DC			DC			
	Plastic	DB			DB			DB			DB			

*Denotes commercial temperature range device
**Applies over temperature
†149/349 ($A_{V_{min}}$ = 5) parameter
‡Denotes industrial temperature range device
(1) Gain-bandwidth product ($A_{V_{min}}$ = 5)
(2) Input noise voltage = 2 μV RMS max (20 Hz to 20 kHz)