OP-77 Series Precision Operational Amplifiers

Features

- Ultra high gain – 5000 V/mV min
- Outstanding gain linearity
- Ultra low V_{os} drift – 0.3 μV/°C max
- Low V_{os} – 25 μV max
- Low noise – 0.3 μV_{p-p} (0.1 to 10 Hz)
- Low power consumption – 35 mW
- Low input offset current – 1.5 nA max
- High CMRR – 120 dB min
- High PSRR – 110 dB min
- Replaces OP-07, 108, 725, 741 types
- Wide range of package types

Description

Designed to upgrade OP-07 and other similar precision op amps, the OP-77 offers ultra high performance in applications requiring high gain, superior gain-linearity, and extremely low TCV_{os}. The OP-77's outstanding gain-linearity, which eliminates incorrectable system nonlinearities common in previous precision op amps, is achieved by an exceptional open-loop gain of more than 10 million maintained over ±10V output range. The excellent TCV_{os} of 0.3 μV/°C maximum, plus an extremely low power consumption of 35 mW (which reduces warm-up drift) significantly increases system accuracy over temperature. These characteristics, along with low V_{os}, low I_{os}, high CMRR, high PSRR, and low input noise levels, combine to raise the performance level of many high-resolution instrumentation and data conversion systems.

Advanced circuit design and wafer processing are Raytheon's added advantages in quality and reliability. A patented, proprietary V_{os} trimming method after packaging significantly enhances yield and availability of top grade (A/E) devices.

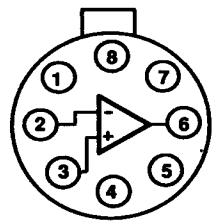
Ordering Information

Part Number	Package	Operating Temperature Range
OP-77EN	N	0°C to +70°C
OP-77FN	N	0°C to +70°C
OP-77GN	N	0°C to +70°C
OP-77FM	M	0°C to +70°C
OP-77GM	M	0°C to +70°C
OP-77ET	T	-25°C to +85°C
OP-77FT	T	-25°C to +85°C
OP-77ED	D	-25°C to +85°C
OP-77FD	D	-25°C to +85°C
OP-77AT	T	-55°C to +125°C
OP-77AT/883B*	T	-55°C to +125°C
OP-77BT	T	-55°C to +125°C
OP-77BT/883B*	T	-55°C to +125°C
OP-77AD	D	-55°C to +125°C
OP-77AD/883B*	D	-55°C to +125°C
OP-77BD	D	-55°C to +125°C
OP-77BD/883B*	D	-55°C to +125°C
OP-77AL/883B*	L	-55°C to +125°C
OP-77BL/883B*	L	-55°C to +125°C

Notes:
/883B suffix denotes Mil-Std-883, Level B processing
N = 8-lead plastic DIP
D = 8 lead ceramic DIP
T = 8-lead metal can (TO-99)
L = 20-pad leadless chip carrier
M = 8-lead plastic SOIC
Contact a Raytheon sales office or representative for ordering information on special package/temperature range combinations.

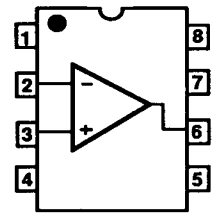
Connection Information

8-Lead TO-99 Metal Can
(Top View)



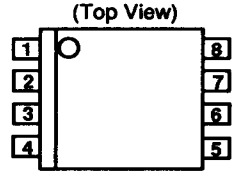
65-03205A

8-Lead Dual In-Line Package
(Top View)



65-03206A

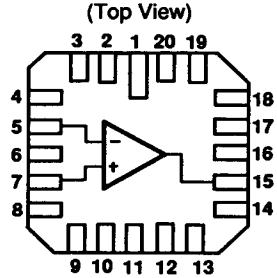
8-Lead Plastic Dual In-Line SO-8
(Top View)



65-02666A

Pin	Function
1	V_{os} Trim
2	-Input
3	+Input
4	$-V_s$(Case)
5	NC
6	Output
7	$+V_s$
8	V_{os} Trim

20-Pad LCC
(Top View)



65-02657A

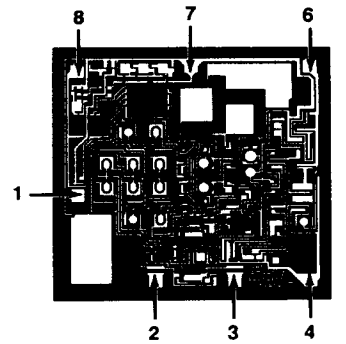
2	V_{os} Trim
5	-Input
7	+Input
10	$-V_s$
15	Output
17	$+V_s$
20	V_{os} Trim

Absolute Maximum Ratings

Supply Voltage ..... ±22V
Input Voltage* ..... ±22V
Differential Input Voltage 30V
Internal Power Dissipation** ..... 500 mW
Output Short Circuit Duration ..... Indefinite
Storage Temperature
Range ..... -65°C to +150°C
Operating Temperature Range
OP77A,B ..... -55°C to +125°C
OP77E,F,G (Hermetic) ..... -25°C to +85°C
OP77E,F,G (Plastic) ..... 0°C to +70°C
Lead Soldering Temperature
TO-99, DIP, LCC (60 sec) ..... +300°C
SO-8 (10 sec) ..... +260°C

*For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.
**Observe package thermal characteristics.

Mask Pattern



Die Size: 75 x 78 mils
Min. Pad Dimensions: 4 x 4 mils

Thermal Characteristics

	20-Pad LCC	8-Lead Ceramic DIP	8-Lead TO-99 Metal Can	8-Lead Plastic SO	8-Lead Plastic DIP
Max. Junction Temp.	175°C	175°C	175°C	125°C	125°C
Max. P_D T_A <50°C	925 mW	833 mW	658 mW	300 mW	468 mW
Therm. Res θ_{JC}	37°C/W	45°C/W	50°C/W	–	–
Therm. Res. θ_{JA}	105°C/W	150°C/W	190°C/W	240°C/W	160°C/W
For T_A >50°C Derate at	7.0 mW/°C	8.33 mW/°C	5.26 mW/°C	4.17 mW/°C	6.25 mW/°C

Electrical Characteristics (V_S = ±15V and T_A = +25°C unless otherwise noted)

Parameters	Test Conditions	OP-77A			OP-77B			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[3]			±10	±25		±20	±60	µV
Long Term V_{OS} Stability[1]			0.2			0.2		µV/Mo
Input Offset Current			±0.3	±1.5		±0.3	±2.8	nA
Input Bias Current			±1.2	±2.0		±1.2	±2.8	nA
Input Noise Voltage[5]	0.1 Hz to 10 Hz		0.35	0.6		0.35	0.65	μV_{p-p}
Input Noise Voltage Density[5]	F_O = 10 Hz		10.3	18		10.3	18	$\frac{nV}{\sqrt{Hz}}$
	F_O = 100 Hz		10	13		10	13	
	F_O = 1000 Hz		9.6	11		9.6	11	
Input Noise Current[5]	0.1 Hz to 10 Hz		14	30		14	35	pA_{p-p}
Input Noise Current Density[5]	F_O = 10 Hz		0.32	0.8		0.32	0.8	$\frac{pA}{\sqrt{Hz}}$
	F_O = 100 Hz		0.14	0.23		0.14	0.23	
	F_O = 1000 Hz		0.12	0.17		0.12	0.17	
Input Resistance (Diff. Mode)[2]		26	45		18.5	45		MΩ
Input Resistance (Com. Mode)			200			200		GΩ
Input Voltage Range[4]		±13	±14		±13	±14		V
Common Mode Rejection Ratio	V_{CM} = ±11V	120	140		116	140		dB
Power Supply Rejection Ratio	V_S = ±3V to ±8V	110	120		110	120		dB
Large Signal Voltage Gain	R_L ≥2 kΩ, V_O = ±10V	5000	12000		2000	8000		V/mV
Output Voltage Swing	R_L ≥10 kΩ,	±13	±13.5		±13	±13.5		V
	R_L ≥2 kΩ,	±12.5	±13		±12.5	±13		
	R_L ≥1 kΩ,	±12	±12.5		±12	±12.5		
Slew Rate[2]	R_L ≥2 kΩ,	0.1	0.2		0.1	0.2		V/µS
Closed Loop Bandwidth[2]	A_{VCL} = +1.0	0.4	0.6		0.4	0.6		MHz
Open Loop Output Resistance	V_O = 0, I_O = 0		60			60		Ω
Power Consumption	V_S = ±15V, R_L = ∞		35	60		35	60	mW
	V_S = ±3V, R_L = ∞		2.0	4.5		2.0	4.5	
Offset Adjustment Range	R_P = 20 kΩ		±3.5			±3.5		mV

Notes:
1. Long Term Input Offset Voltage Stability refers to the averaged trend line of V_{OS} vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5 µV.
2. Guaranteed by design.
3. Input Offset Voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power. The OP-77A/E grades in T, D, and L packages are tested fully warmed up.
4. The input protection diodes do not allow the device to be removed or inserted into the circuit without first removing power.
5. Sample tested.

Electrical Characteristics (V_S = ±15V and T_A = +25°C unless otherwise noted)

Parameters	Test Conditions	OP-77E			OP-77F			OP-77G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[3]			±10	±25		±20	±60		±50	±100	µV
Long Term Input Offset Voltage Stability[1]			0.3			0.4			0.4		µV/Mo
Input Offset Current			±0.3	±1.5		±0.3	±2.8		±0.3	±2.8	nA
Input Bias Current			±1.2	±2.0		±1.2	±2.8		±1.2	±2.8	nA
Input Noise Voltage[5]	0.1 Hz to 10 Hz		0.35	0.6		0.38	0.65		0.38	0.65	μV_{p-p}
Input Noise Voltage Density[5]	F_O = 10 Hz		10.3	18		10.5	20		10.5	20	nV/√Hz
	F_O = 100 Hz		10	13		10.2	13.5		10.2	13.5	
	F_O = 1000 Hz		9.6	11		9.8	11.5		9.8	11.5	
Input Noise Current[5]	0.1 Hz to 10 Hz		14	30		15	35		15	35	pA_{p-p}
Input Noise Current Density[5]	F_O = 10 Hz		0.32	0.8		0.35	0.9		0.35	0.9	pA/√Hz
	F_O = 100 Hz		0.14	0.23		0.15	0.27		0.15	0.27	
	F_O = 1000 Hz		0.12	0.17		0.13	0.18		0.13	0.18	
Input Resistance (Diff. Mode)[2]		26	45		18.5	45		18.5	45		MΩ
Input Resistance (Com. Mode)			200			200			200		GΩ
Input Voltage Range[4]		±13	±14		±13	±14		±13	±14		V
Common Mode Rejection Ratio	V_{CM} = ±13V	120	140		116	140		116	140		dB
Power Supply Rejection Ratio	V_S = ±3V to ±18V	110	123		110	123		110	123		dB
Large Signal Voltage Gain	R_L ≥2 kΩ, V_O = ±10V	5000	12000		2000	6000		2000	6000		V/mV
Output Voltage Swing	R_L ≥10 kΩ	±13	±13.5		±13	±13.5		±13	±13.5		V
	R_L ≥2 kΩ	±12.5	±13		±12.5	±13		±12.5	±13		
	R_L ≥1 kΩ	±12	±12.5		±12	±12.5		±12	±12.5		
Slew Rate[2]	R_L ≥2 kΩ	0.1	0.2		0.1	0.2		0.1	0.2		V/µS
Closed-Loop Bandwidth[2]	A_{VCL} = +1.0	0.4	0.6		0.4	0.6		0.4	0.6		MHz
Open Loop Output Resistance	V_O = 0, I_O = 0		60			60			60		Ω
Power Consumption	V_S = ±15V, R_L = ∞		35	60		35	60		35	60	mW
	V_S = ±3V, R_L = ∞		2.0	4.5		2.0	4.5		2.0	4.5	
Offset Adjustment Range	R_P = 20 kΩ		±3.5			±3.5			±3.5		mV

Notes:
1. Long Term Input Offset Voltage Stability refers to the averaged trend line of V_{OS} vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5 µV.
2. Guaranteed by design.
3. Input Offset Voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power. The OP-77A/E grades on T, D, and L packages are tested fully warmed up.
4. The input protection diodes do not allow the device to be removed or inserted into the circuit without first removing power.
5. Sample tested.

Electrical Characteristics (V_S = ±15V, -55°C ≤ T_A ≤ +125°C unless otherwise noted)

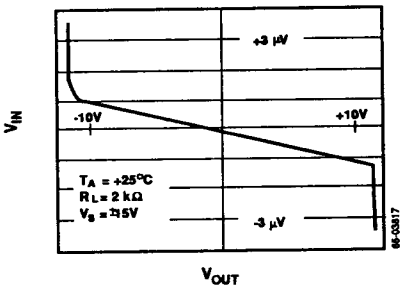
Parameters	Test Conditions	OP-77A			OP-77B			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage			±25	±60		±45	±120	µV
Average Input Offset Voltage Drift[1]			0.1	0.3		0.2	0.6	µV/°C
Input Offset Current			±0.8	±2.2		±1.0	±4.5	nA
Average Input Offset Current Drift[2]			±5.0	±25		±5.0	±50	pA/°C
Input Bias Current			±2.4	±4.0		±2.4	±6.0	nA
Average Input Bias Current Drift[2]			±8.0	±25		±15	±35	pA/°C
Input Voltage Range		±13	±13.5		±13	±13.5		V
Common Mode Rejection Ratio	V_{CM}= ±10V	120	140		110	140		dB
Power Supply Rejection Ratio	V_S = ±3V to ±8V	110	120		106	120		dB
Large Signal Voltage Gain	R_L ≥2 kΩ, V_O = ±10V	2000	6000		1000	4000		V/mV
Maximum Output Voltage Swing	R_L ≥2 kΩ,	±12	±13		±12	±13		V
Power Consumption	R_L = ∞		40	75		40	75	mW

Electrical Characteristics

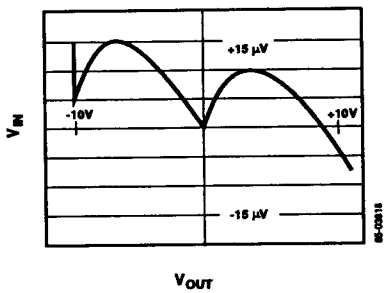
(V_S = ±15V; -25°C ≤ T_A ≤ +85°C for T, D, and L packages; 0°C ≤ T_A ≤ +70°C for N and M packages unless otherwise noted)

Parameters	Test Conditions	OP-77E			OP-77F			OP-77G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage			±10	±45		±20	±100		±80	±100	µV
Average Input Offset Voltage Drift			0.1	0.3		0.2	0.6		0.3	1.2	µV/°C
Input Offset Current			±0.5	±2.2		±0.5	±4.5		±0.5	±4.5	nA
Average Input Offset Current Drift[2]			±1.5	±40		±1.5	±85		±1.5	±85	pA/°C
Input Bias Current			±2.4	±4.0		±2.4	±6.0		±2.4	±6.0	nA
Average Input Bias Current Drift[2]			±8	±40		±15	±60		±15	±60	pA/°C
Input Voltage Range		±13	±13.5		±13	±13.5		±13	±13.5		V
Common Mode Rejection Ratio	V_{CM}= ±13V	120	140		110	140		110	140		dB
Power Supply Rejection Ratio	V_S = ±3V to ±18V	110	120		106	120		106	120		dB
Large Signal Voltage Gain	R_L ≥2 kΩ, V_O = ±10V	2000	6000		1000	4000		1000	4000		V/mV
Output Voltage Swing	R_L ≥2 kΩ	±12	±13		±12	±13		±12	±13		V
Power Consumption	R_L = ∞		40	75		40	75		40	75	mW

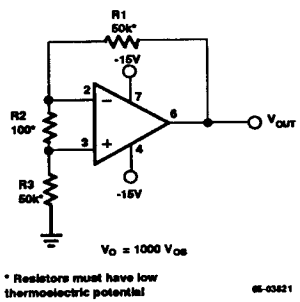
Notes:
1. 100% tested for Grade A on T, and L packages.
2. Sample tested.



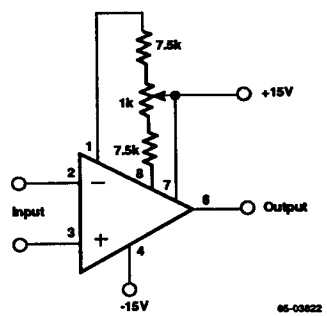
OP-77 Improved Open-Loop Gain Linearity



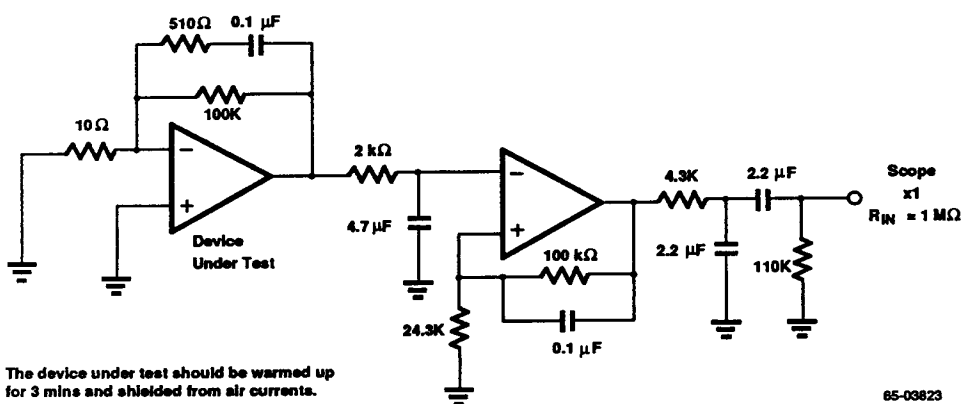
Typical Precision Op Amp Gain Linearity



Test Circuit for Offset Voltage and Its Drift With Temperature

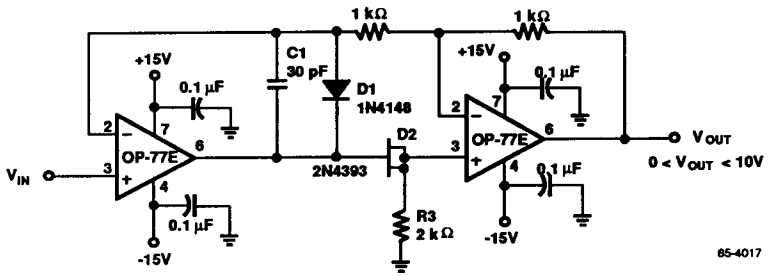


Improved Sensitivity V_{OS} Adjustment



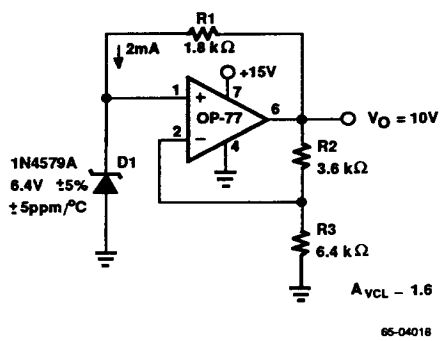
0.1 Hz to 10 Hz Noise Test Circuit
(peak to peak noise measured in 10 sec interval)

Typical Applications



The high gain and low TCV_{OS} assure accurate operation with inputs from microvolts to volts. In this circuit, the signal always appears as a common-mode signal to the op amps. The OP-77E CMRR of 1 µV/V assures errors of less than 2 ppm.

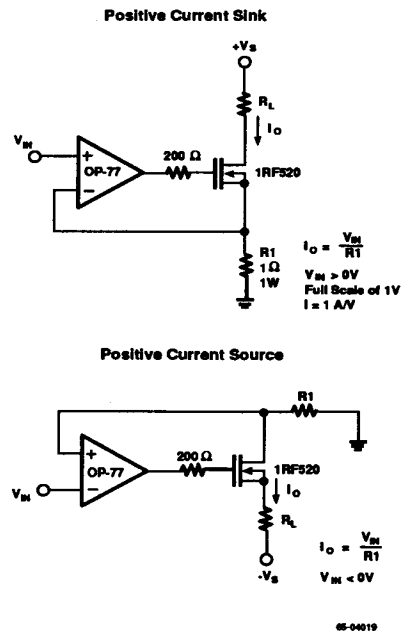
Precision Absolute Value Amplifier



This simple bootstrapped voltage reference provides a precise 10V virtually independent of changes in power supply voltage, ambient temperature and output loading. Correct zener operating current of exactly 2 mA is maintained by R1, a selected 5 ppm/°C resistor, connected to the regulated output. Accuracy is primarily determined by three factors: the 5 ppm/°C temperature coefficient of D1, 1 ppm/°C ratio tracking of R2 and R3, and operational amplifier V_{OS} errors.

V_{OS} errors, amplified by 1.6 (A_{VCL}), appear at the output and can be significant with most monolithic amplifiers. For example: an ordinary amplifier with TCV_{OS} of 5 µV/°C contributes 0.8 ppm/°C of output error while the OP-77, with TCV_{OS} of 0.3 µV/°C, contributes but 0.05 ppm/°C of output error, thus effectively eliminating TCV_{OS} as an error consideration.

High Stability Voltage Reference



These simple high current sinks require that the load float between the power supply and the sink.

In these circuits, OP-77's high gain, high CMRR, and low TCV_{OS} assure high accuracy.

Precision Current Sinks

Simplified Schematic Diagram