

OP-77

Precision Operational Amplifier

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 $\pm 10V$ output range. The excellent TCV_{OS} of $0.1 \mu V/^{\circ}C$, 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 Semiconductor'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.

Features

- ◆ Ultra high gain – 12000 V/mV
- ◆ Outstanding gain linearity
- ◆ Ultra low V_{OS} drift – $0.1 \mu V/^{\circ}C$
- ◆ Low V_{OS} – 10 μV max
- ◆ Low noise – $0.3 \mu V_{p-p}$ (0.1 Hz to 10 Hz)
- ◆ Low power consumption – 35 mW
- ◆ Low input offset current — 0.3 nA
- ◆ High CMRR – 140 dB min
- ◆ High PSRR – 120 dB min
- ◆ Replaces OP-07, 108, 741 types
- ◆ Wide range of package types

OP-77

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-77EM	M	0°C to +70°C
OP-77FM	M	0°C to +70°C
OP-77GM	M	0°C to +70°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

Notes:

/883B suffix denotes Mil-Std-883, Level B processing

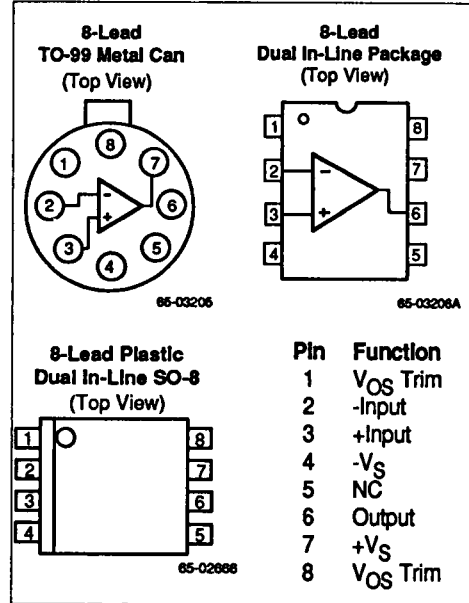
N = 8-lead plastic DIP

D = 8 lead ceramic DIP

T = 8-lead metal can (TO-99)

M = 8-lead plastic SOIC

Connection Information



Absolute Maximum Ratings

Supply Voltage	$\pm 22\text{V}$
Input Voltage ¹	$\pm 22\text{V}$
Differential Input Voltage	30V
Internal Power Dissipation ²	500 mW
Output Short Circuit Duration	Indefinite
Storage Temperature	
Range	-65°C to $+150^{\circ}\text{C}$
Operating Temperature Range	
OP77A,B	-55°C to $+125^{\circ}\text{C}$
OP77E,F,G	0°C to $+70^{\circ}\text{C}$
Lead Soldering Temperature	
TO-99, DIP, (60 sec)	$+300^{\circ}\text{C}$
SO-8 (10 sec)	$+260^{\circ}\text{C}$

Notes:

1. For supply voltages less than $\pm 22\text{V}$, the absolute maximum input voltage is equal to the supply voltage.
2. Observe package thermal characteristics.

Thermal Characteristics

	8-Lead Ceramic DIP	8-Lead TO-99 Metal Can	8-Lead Small Outline	8-Lead Plastic DIP
Max. Junction Temp.	$+175^{\circ}\text{C}$	$+175^{\circ}\text{C}$	$+125^{\circ}\text{C}$	$+125^{\circ}\text{C}$
Max. P_D $T_A < 50^{\circ}\text{C}$	833 mW	658 mW	300 mW	468 mW
Therm. Res θ_{JC}	45°C/W	50°C/W	—	—
Therm. Res. θ_{JA}	150°C/W	190°C/W	240°C/W	160°C/W
For $T_A > 50^{\circ}\text{C}$ Derate at	8.33 mW/ $^{\circ}\text{C}$	5.26 mW/ $^{\circ}\text{C}$	4.17 mW/ $^{\circ}\text{C}$	6.25 mW/ $^{\circ}\text{C}$

Linear

OP-77

Electrical Characteristics

($V_S = \pm 15V$ and $T_A = +25^\circ C$ 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		$\mu V/Mo$
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	$\frac{\mu V}{\sqrt{Hz}}$
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	$\frac{nA}{\sqrt{Hz}}$
Input Resistance (Diff. Mode) ²		26	45		18.5	45		M Ω
Input Resistance (Com. Mode)			200			200		G Ω
Input Voltage Range ⁴		± 13	± 14		± 13	± 14		V
Common Mode Rejection Ratio	$V_{CM} = \pm 11V$	120	140		116	140		dB
Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 8V$	110	120		110	120		dB
Large Signal Voltage Gain	$R_L \geq 2$ k Ω , $V_{OUT} = \pm 10V$	5000	12000		2000	8000		V/mV
Output Voltage Swing	$R_L \geq 10$ k Ω	± 13	± 13.5		± 13	± 13.5		V
	$R_L \geq 2$ k Ω	± 12.5	± 13		± 12.5	± 13		
	$R_L \geq 1$ k Ω	± 12	± 12.5		± 12	± 12.5		
Slew Rate ²	$R_L \geq 2$ k Ω	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	$V_{OUT} = 0$, $I_{OUT} = 0$		60			60		Ω
Power Consumption	$V_S = \pm 15V$, $R_L = \infty$		35	60		35	60	mW
	$V_S = \pm 3V$, $R_L = \infty$		2.0	4.5		2.0	4.5	
Offset Adjustment Range	$R_{TRIM} = 20$ k Ω		± 3.5			± 3.5		mV

Notes:

1. Long Term Input Offset Voltage Stability refers to the average 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 grade 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

($V_S = \pm 15V$ and $T_A = +25^\circ C$ 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		$\mu V/Mo$
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
	$F_O = 100$ Hz		10	13		10.2	13.5		10.2	13.5	\sqrt{Hz}
	$F_O = 1000$ Hz		9.6	11		9.8	11.5		9.8	11.5	\sqrt{Hz}
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
	$F_O = 100$ Hz		0.14	0.23		0.15	0.27		0.15	0.27	\sqrt{Hz}
	$F_O = 1000$ Hz		0.12	0.17		0.13	0.18		0.13	0.18	\sqrt{Hz}
Input Resistance (Diff. Mode) ²		26	45		18.5	45		18.5	45	$M\Omega$	
Input Resistance (Com. Mode)			200			200			200	$G\Omega$	
Input Voltage Range ⁴		± 13	± 14		± 13	± 14		± 13	± 14	V	
Common Mode Rejection Ratio	$V_{CM} = \pm 13V$	120	140		116	140		116	140	dB	
Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 18V$	110	123		110	123		110	123	dB	
Large Signal Voltage Gain	$R_L \geq 2 k\Omega$ $V_{OUT} = \pm 10V$	5000	12000		2000	6000		2000	6000	V/mV	
Output Voltage Swing	$R_L \geq 10 k\Omega$	± 13	± 13.5		± 13	± 13.5		± 13	± 13.5	V	
	$R_L \geq 2 k\Omega$	± 12.5	± 13		± 12.5	± 13		± 12.5	± 13	V	
	$R_L \geq 1 k\Omega$	± 12	± 12.5		± 12	± 12.5		± 12	± 12.5	V	
Slew Rate ²	$R_L \geq 2 k\Omega$	0.1	0.2		0.1	0.2		0.1	0.2	$V/\mu S$	
Closed-Loop Bandwidth ²	$A_{VOL} = +1.0$	0.4	0.6		0.4	0.6		0.4	0.6	MHz	
Open Loop Output Resistance	$V_{OUT} = 0, I_{OUT} = 0$		60			60			60	Ω	
Power Consumption	$V_S = \pm 15V, R_L = \infty$		35	60		35	60		35	60	mW
	$V_S = \pm 3V, R_L = \infty$		2.0	4.5		2.0	4.5		2.0	4.5	mW
Offset Adjustment Range	$R_{TRIM} = 20 k\Omega$		± 3.5			± 3.5			± 3.5		mV

Notes:

1. Long Term Input Offset Voltage Stability refers to the average 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 $2.5 \mu V$.
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-77E grade 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.

OP-77

Electrical Characteristics

($V_S = \pm 15V$, $-55^\circ C \leq T_A \leq +125^\circ C$ 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	$\mu V/^\circ C$
Input Offset Current			± 0.8	± 2.2		± 1.0	± 4.5	nA
Average Input Offset Current Drift ²			± 5.0	± 25		± 5.0	± 50	$\mu A/^\circ C$
Input Bias Current			± 2.4	± 4.0		± 2.4	± 6.0	nA
Average Input Bias Current Drift ²			± 8.0	± 25		± 15	± 35	$\mu A/^\circ C$
Input Voltage Range		± 13	± 13.5		± 13	± 13.5		V
Common Mode Rejection Ratio	$V_{CM} = \pm 10V$	120	140		110	140		dB
Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 8V$	110	120		106	120		dB
Large Signal Voltage Gain	$R_L \geq 2 k\Omega$ $V_{OUT} = \pm 10V$	2000	6000		1000	4000		V/mV
Maximum Output Voltage Swing	$R_L \geq 2 k\Omega$	± 12	± 13		± 12	± 13		V
Power Consumption	$R_L = \infty$		40	75		40	75	mW

Electrical Characteristics

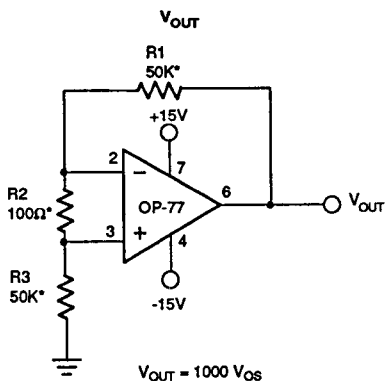
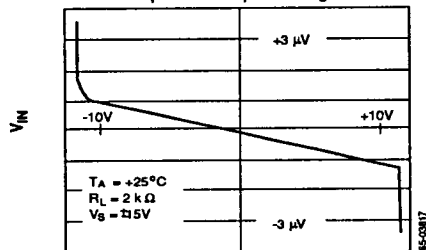
($V_S = \pm 15V$, $0^\circ C \leq T_A \leq +70^\circ C$ unless otherwise noted)

Parameters	Test Conditions	OP-77E			OP-77F			OP-77G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage			± 10	± 45		± 20	± 100		± 80	± 100	μV
Average Input Offset Voltage Drift			0.1	0.3		0.2	0.6		0.3	1.2	$\mu V/^\circ C$
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	$\mu A/^\circ C$
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	$\mu A/^\circ C$
Input Voltage Range		± 13	± 13.5		± 13	± 13.5		± 13	± 13.5		V
Common Mode Rejection Ratio	$V_{CM} = \pm 13V$	120	140		110	140		110	140		dB
Power Supply Rejection Ratio	$V_S = \pm 3V$ to $\pm 18V$	110	120		106	120		106	120		dB
Large Signal Voltage Gain	$R_L \geq 2 k\Omega$ $V_{OUT} = \pm 10V$	2000	6000		1000	4000		1000	4000		V/mV
Output Voltage Swing	$R_L \geq 2 k\Omega$	± 12	± 13		± 12	± 13		± 12	± 13		V
Power Consumption	$R_L = \infty$		40	75		40	75		40	75	mW

- Notes: 1. 100% tested for Grade A and T packages.
2. Sample tested.

Typical Performance Characteristics

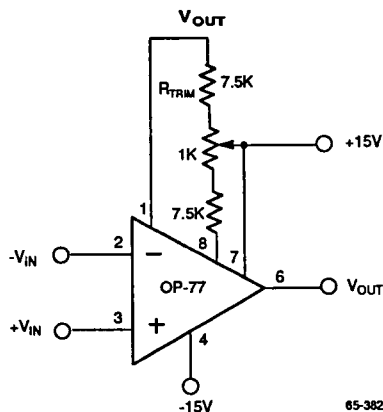
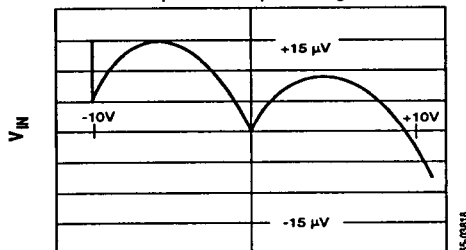
OP-77 Improved Open-Loop Gain Linearity
Input vs. Output Voltage



* Resistors must have low thermoelectric potential

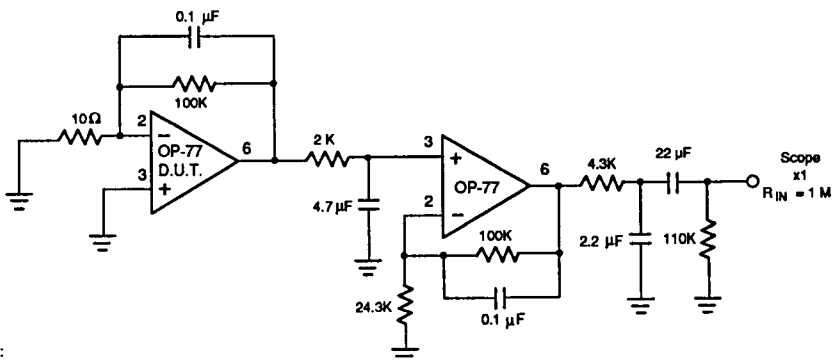
65-03821

Typical Precision Op Amp Gain Linearity
Input vs. Output Voltage



65-3822

Test Circuit for Input Offset Voltage and
Its Drift with Temperature



Notes:

1. Peak-to-Peak noise measured in a 10-second interval.
2. The device under test should be warmed up for 3 minutes and shielded from air currents.
3. Voltage Gain = 50,000
4. All capacitor values are for non-polarized capacitors only.
5. Pin numbers shown are for 8-lead packages.

65-03823B

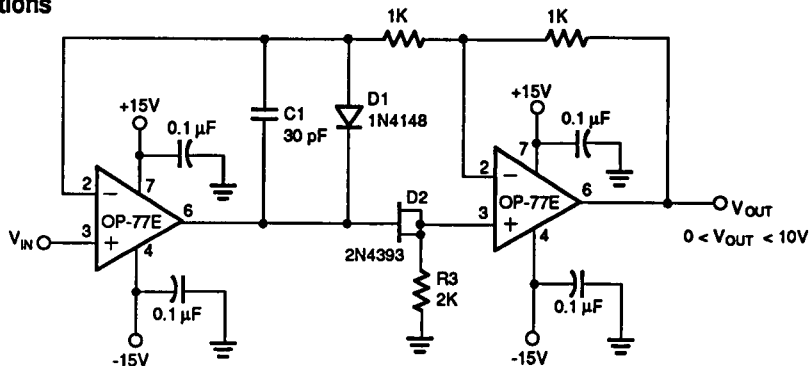
0.1 Hz to 10 Hz Noise Test Circuit

Input Offset Voltage Adjustment

Linear

OP-77

Typical Applications

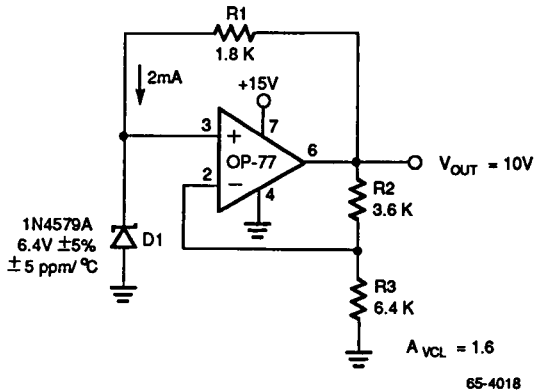


The high gain and low TCV_{OS} assure accurate operation with inputs from microvolts to volts. In this circuit, the signal always appears as a common-mode signal to the op amps. The OP-77E CMRR of $1 \mu V/V$ assures errors of less than 2 ppm.

65-4017

Precision Absolute Value Amplifier

Positive Current Sink

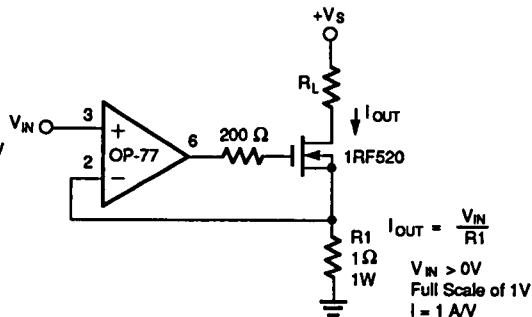


65-4018

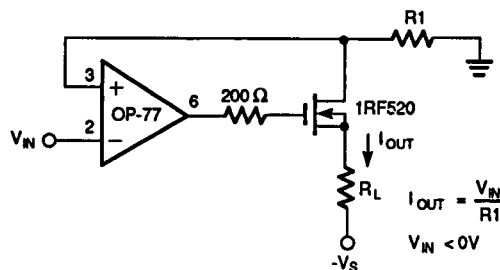
This simple bootstrapped voltage reference provides a precise 10V virtually independent of changes in power supply voltage, ambient temperature and output loading. Correct zener operating current of exactly 2 mA is maintained by R1, a selected 5 ppm/°C resistor, connected to the regulated output. Accuracy 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 $5 \mu V/^\circ C$ contributes 0.8 ppm/°C of output error while the OP-77, with TCV_{OS} of $0.3 \mu V/^\circ C$, contributes but 0.05 ppm/°C of output error, thus effectively eliminating TCV_{OS} as an error consideration.

High Stability Voltage Reference



Positive Current Source



65-4019

This simple high current sink/source requires that the load float between the power supply and the sink/sources.

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

Precision Current Sinks