ANALOG DEVICES

Low Power, Low Noise Precision FET Op Amp

AD795

FEATURES

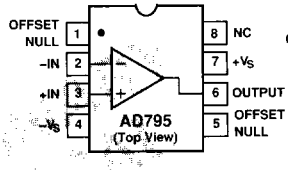
- Low Power Replacement for Burr-Brown OPA-111, OPA-121 Op Amp and TI TLC 2201
- Low Noise
  - 2.5 μV p–p max, 0.1 Hz to 10 Hz
  - 10 nV/√Hz max at 10 kHz
  - 0.6 fA/√Hz at 1 kHz
- High DC Accuracy
  - 250 μV max Offset Voltage
  - 1 μV/°C max Drift
  - 1 pA max Input Bias Current
  - 114 dB Open-Loop Gain
- Available in Plastic Mini-DIP, 8-Pin Header and Surface Mount (SOIC) Packages
- Dual Version AD796 also Available

APPLICATIONS

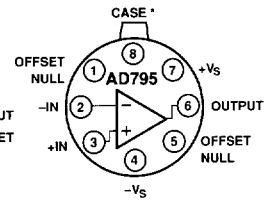
- Low Noise Photodiode Preamps
- CT Scanners
- Precision I-to-V Converters

CONNECTION DIAGRAMS

8-Pin Plastic Mini-DIP (N) Package

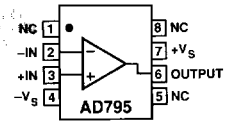


TO-99 (H) Package



* NOTE: CASE CONNECTED TO PIN 8.

8-Pin SOIC (R) Package



PRODUCT DESCRIPTION

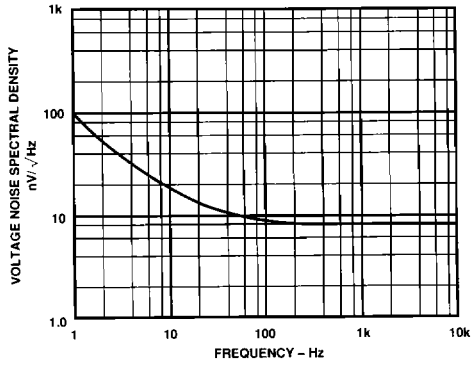
The AD795 is a low noise, precision, FET input operational amplifier. It offers both the low voltage noise and low offset drift of a bipolar input op amp and the very low bias current of a FET-input device. The 10^{14} Ω common-mode impedance insures that input bias current is essentially independent of common-mode voltage variations.

The AD795 has both excellent dc performance and a guaranteed and tested maximum input voltage noise. It features 1 pA maximum input bias current and 250 μV maximum offset voltage, along with low supply current of 1.5 mA max.

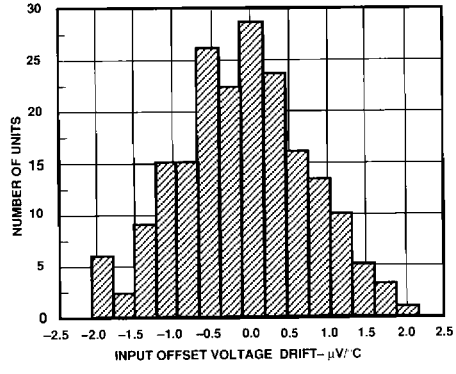
Furthermore, the AD795 features a guaranteed low input noise of 2.5 μV p–p (0.1 Hz to 10 Hz) and a 10 nV/√Hz max noise level at 10 kHz. The AD795 has a fully specified and tested input offset voltage drift of only 1 μV/°C max which is trimmed at the wafer level to keep device cost low.

The AD795 is useful for many high input impedance, low noise applications. It is available in five performance grades. The AD795J and AD795K are rated over the commercial temperature range of 0°C to +70°C. The AD795A and AD795B are rated over the industrial temperature of −40°C to +85°C. The AD795SQ/883B is rated over the military temperature range of −55°C to +125°C and is processed to MIL-STD-883B.

The AD795 is available in 8-pin plastic mini-DIP, 8-pin header, and 8-pin surface mount (SOIC) packages.



AD795 Voltage Noise Spectral Density



Typical Distribution of Average Input Offset

AD795—SPECIFICATIONS (@ +25°C and ±15 V dc, unless otherwise noted)

Parameter	Conditions	AD795J/A Min	AD795J/A Typ	AD795J/A Max	AD795K/B Min	AD795K/B Typ	AD795K/B Max	AD795S Min	AD795S Typ	AD795S Max	Units
INPUT OFFSET VOLTAGE[1]											
Initial Offset			100	500		50	250		100	500	μV
Offset	T_{MIN}–T_{MAX}		300	1000		100	400		500	1500	μV
vs. Temperature			3	10/5		2	3/1		4	10	μV/°C
vs. Supply		90	110		94	110		90	110		dB
vs. Supply (PSRR)	T_{MIN}–T_{MAX}		100		90	100		86	95		dB
INPUT BIAS CURRENT[2]											
Either Input	V_{CM} = 0 V		1	2		1	1		1	4	pA
Either Input @ T_{MAX} =	V_{CM} = 0 V		23/64			23/64			1000		pA
Either Input	V_{CM} = +10 V		1			1			1		pA
Offset Current	V_{CM} = 0 V		0.1	1.0		0.1	0.5		0.1	1.0	pA
Offset Current @ T_{MAX} =	V_{CM} = 0 V		2/6			2/6			100		pA
INPUT VOLTAGE NOISE	0.1 Hz to 10 Hz		1.0	3.3		1.0	2.5		1.0	3.3	μV p–p
	f = 10 Hz		20	50		20	40		20	50	nV/√Hz
	f = 100 Hz		10	30		10	20		10	30	nV/√Hz
	f = 1 kHz		9	15		9	10		7	15	nV/√Hz
	f = 10 kHz		8	10		8	10		8	10	nV/√Hz
INPUT CURRENT NOISE	f = 0.1 Hz to 10 Hz		13			13			13		fA p–p
	f = 1 kHz		0.6			0.6			0.6		fA/√Hz
FREQUENCY RESPONSE											
Unity Gain, Small Signal	G = −1		1.6			1.6			1.6		MHz
Full Power Response	V_O = 20 V p–p, R_{LOAD} = 2 kΩ		16			16			16		kHz
Slew Rate, Unity Gain	V_{OUT} = 20 V p–p, R_{LOAD} = 2 kΩ		1			1			1		V/μs
SETTLING TIME[3]											
To 0.1%			6			6			6		μs
To 0.01%			8			8			8		μs
Overload Recovery[4]	50% Overdrive		5			5			5		μs
Total Harmonic Distortion	f = 1 kHz, Rl ≥ 2 kΩ, V_O = 3 V rms		0.0006			0.0006			0.0006		%
INPUT IMPEDANCE											
Differential	V_{DIFF} = ±1 V		10^{12}|1			10^{12}|1			10^{12}|1		Ω|pF
Common Mode			10^{14}|2.2			10^{14}|2.2			10^{14}|2.2		Ω|pF
INPUT VOLTAGE RANGE											
Differential[5]			±20			±20			±20		V
Common-Mode Voltage		±10	±11		±10	±11		±10	±11		V
Over Max Operating Range		±10			±10			±10			V
Common-Mode Rejection Ratio	V_{CM} = ±10 V	90	110		94	110		90	110		dB
	T_{MIN} to T_{MAX}		100		90	100		86	100		dB
OPEN-LOOP GAIN	V_O = ±10 V										
	R_{LOAD} ≥ 10 kΩ		120			120			120		dB
	R_{LOAD} ≥ 2 kΩ	100	108		100	108		100	108		dB
	T_{MIN}–T_{MAX}				114			110			dB
OUTPUT CHARACTERISTICS											
Voltage	R_{LOAD} ≥ 2 kΩ	±10	±11		±10	±11		±10	±11		V
	T_{MIN}–T_{MAX}	±10			±10			±10			V
Current	V_{OUT} = ±10 V	±5	±10		±5	±10		±5	±10		mA
	Short Circuit		±15			±15			±15		mA
POWER SUPPLY											
Rated Performance			±15			±15			±15		V
Operating Range		±5		±18	±5		±18	±5		±18	V
Quiescent Current			1.2	1.5		1.2	1.5		1.2	1.5	mA

This information applies to a product under development. Its characteristics and specifications are subject to change without notice. Analog Devices assumes no obligation regarding future manufacture unless otherwise agreed to in writing.

NOTES
[1]Input offset voltage specifications are guaranteed after 5 minutes of operation at T_A = +25°C.
[2]Bias current specifications are guaranteed maximum at either input after 5 minutes of operation at T_A = +25°C. For higher temperature, the current doubles every 10°C.
[3]Gain = −1, R1 = 2 kΩ.
[4]Defined as the time required for the amplifier's output to return to normal operation after removal of a 50% overload from the amplifier input.
[5]Defined as the maximum continuous voltage between the inputs such that neither input exceeds ±10 V from ground.

All min and max specifications are guaranteed.
Specifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS[1]

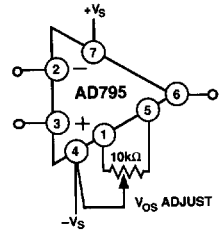
Supply Voltage . . . . . ±18 V
Internal Power Dissipation[2] (@ T_A = +25°C)
  8-Pin Header Package . . . . . 500 mW
  8-Pin Mini-DIP Package . . . . . 750 mW
Input Voltage . . . . . $\pm V_S$
Output Short Circuit Duration . . . . . Indefinite
Differential Input Voltage . . . . . $+V_S$ and $-V_S$
Storage Temperature Range (H) . . . . . −65°C to +150°C
Storage Temperature Range (N, R) . . . . . −65°C to +125°C
Operating Temperature Range
  AD795J/K . . . . . 0°C to +70°C
  AD795A/B . . . . . −40°C to +85°C

NOTES
[1]Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2]8-Pin Plastic Mini-DIP Package: θ_{JA} = 100°C/Watt
8-Pin Header Package: θ_{JA} = 200°C/Watt
8-Pin Small Outline Package: θ_{JA} = 155°C/Watt

ORDERING GUIDE

Model	Temperature Range	Package Option*
AD795JN	0°C to +70°C	N-8
AD795KN	0°C to +70°C	N-8
AD795JR	0°C to +70°C	R-8
AD795AH	−40°C to +85°C	H-08A
AD795BH	−40°C to +85°C	H-08A
AD795SH-883B	−55°C to +125°C	H-08A

*N = Plastic mini-DIP; H-08A = Metal can; R = SOIC package. For outline information see Package Information section.



Offset Null Configuration

AD795—Typical Characteristics

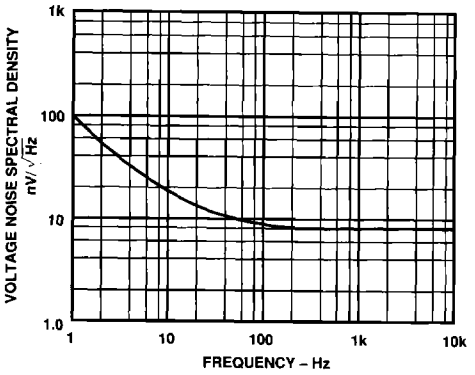


Figure 1. Voltage Noise Spectral Density

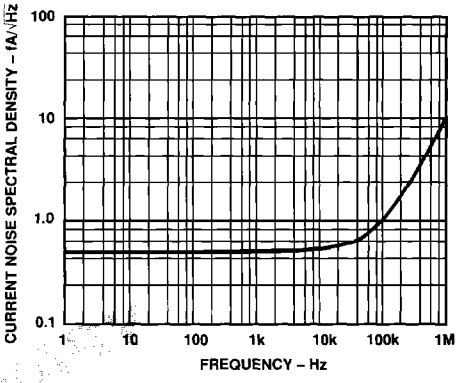


Figure 2. Current Noise Spectral Density

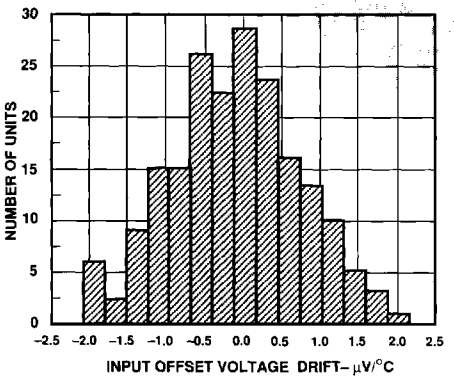


Figure 3. Typical Distribution of Average Input Offset Voltage Drift

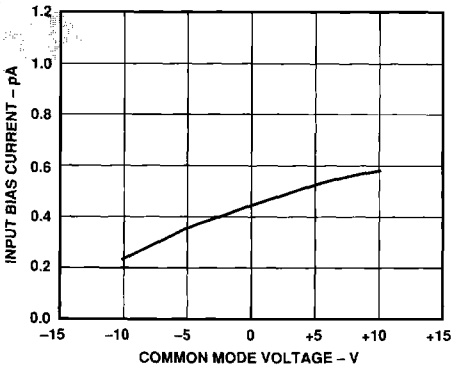


Figure 4. Input Bias Current vs. Common-Mode Voltage

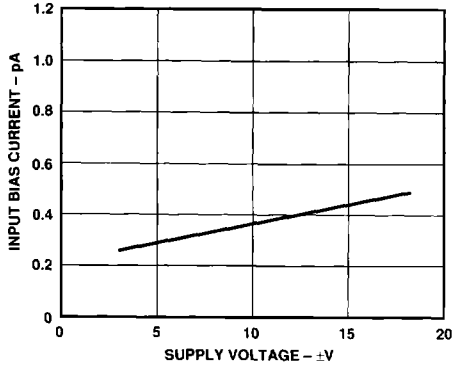


Figure 5. Input Bias Current vs. Supply Voltage

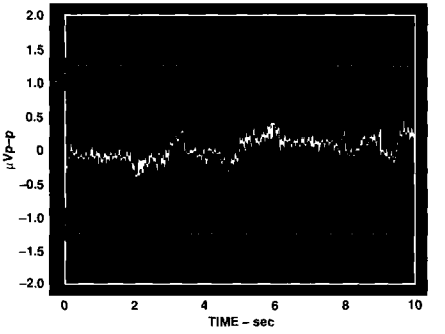


Figure 6. 0.1 Hz to 10 Hz Noise Voltage

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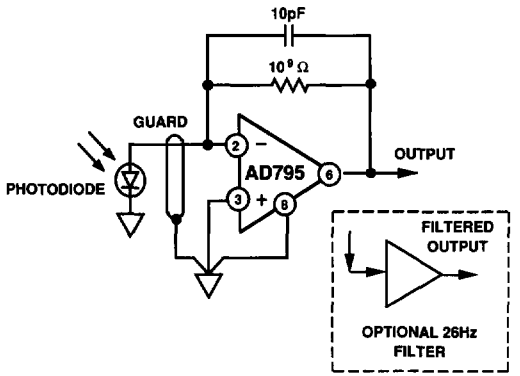

Figure 7. The AD795 Used as a Sensitive Preamplifier

Preamplifier Applications

The low input current and offset voltage levels of the AD795 together with its low voltage noise make this amplifier an excellent choice for preamplifiers used in sensitive photodiode applications. In a typical preamp circuit, shown in Figure 7, the output of the amplifier is equal to:

$$V_{OUT} = I_D\,(Rf) = Rp\,(P)\,Rf$$

where:

I_D = photodiode signal current (Amps)

Rp = photodiode sensitivity (Amp/Watt)

Rf = the value of the feedback resistor, in ohms.

P = light power incident to photodiode surface, in watts.

An equivalent model for a photodiode and its dc error sources is shown in Figure 8. The amplifier's input current, I_B, will contribute an output voltage error which will be proportional to the value of the feedback resistor. The offset voltage error, V_{OS}, will cause a "dark" current error due to the photodiode's finite shunt resistance, Rd. The resulting output voltage error, V_E, is equal to:

$$V_E = (1 + Rf/Rd)\,V_{OS} + Rf\,I_B$$

A shunt resistance on the order of 10^9 ohms is typical for a small photodiode. Resistance Rd is a junction resistance which will typically drop by a factor of two for every 10°C rise in temperature. In the AD795, both the offset voltage and drift are low, this helps minimize these errors.

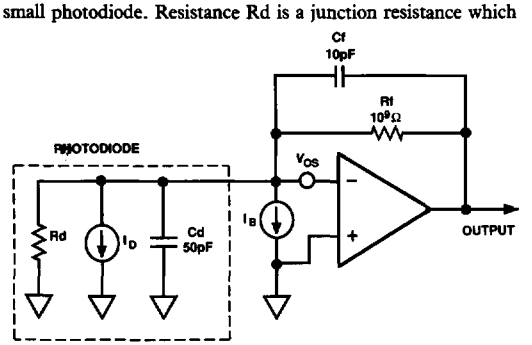

Figure 8. A Photodiode Model Showing DC Error Sources

Minimizing Noise Contributions

The noise level limits the resolution obtainable from any preamplifier. The total output voltage noise divided by the feedback resistance of the op amp defines the minimum detectable signal current. The minimum detectable current divided by the photodiode sensitivity is the minimum detectable light power.

Sources of noise in a typical preamp are shown in Figure 9. The total noise contribution is defined as:

$$\overline{V_{OUT}} = \sqrt{(\overline{i_s^2} + \overline{i_n^2} + \overline{i_t^2})\left(\frac{Rf}{1 + s\,(Cf)\,Rf}\right)^2 + (\overline{en^2})\left(1 + \frac{Rf}{Rd}\left(\frac{1 + s\,(Cd)\,Rd}{1 + s\,(Cf)\,Rf}\right)\right)^2}$$

Figure 10, a spectral density versus frequency plot of each source's noise contribution, shows that the bandwidth of the amplifier's input voltage noise contribution is much greater than its signal bandwidth. In addition, capacitance at the summing junction results in a "peaking" of noise gain in this configuration. This effect can be substantial when large photodiodes with large shunt capacitances are used. Capacitor Cf sets the signal bandwidth and also limits the peak in the noise gain. Each source's rms or root-sum-square contribution to noise is obtained by integrating the sum of the squares of all the noise sources and then by obtaining the square root of this sum. Minimizing the total area under these curves will optimize the preamplifier's overall noise performance.

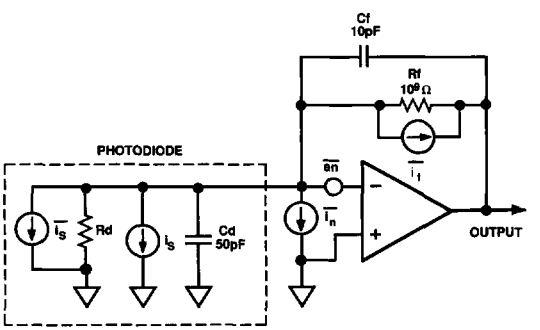

Figure 9. Noise Contributions of Various Sources

An output filter with a passband close to that of the signal can greatly improve the preamplifier's signal to noise ratio. The photodiode preamplifier shown in Figure 9—without a bandpass filter—has a total output noise of 50 μV rms. Using a 26 Hz single pole output filter, the total output noise drops to 23 μV rms, a factor of 2 improvement with no loss in signal bandwidth.

Using a "T" Network

A "T" network, shown in Figure 11, can be used to boost the effective transimpedance of an I to V converter, for a given feedback resistor value. Unfortunately, amplifier noise and offset voltage contributions are also amplified by the "T" network gain. A low noise, low offset voltage amplifier, such as the AD795, is needed for this type of application.

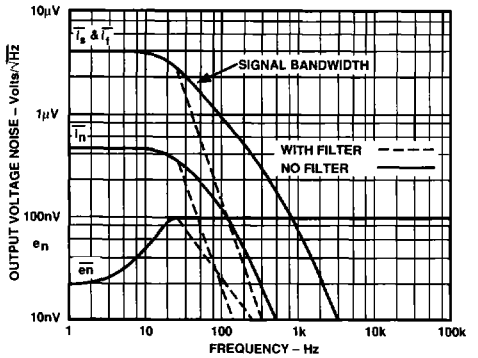

Figure 10. Voltage Noise Spectral Density of the Circuit of Figure 9 with and without an Output Filter

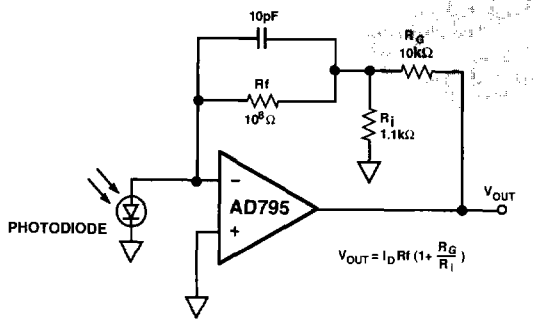

Figure 11. A Photodiode Preamp Employing a "T" Network for Added Gain

A pH Probe Buffer Amplifier

A typical pH probe requires a buffer amplifier to isolate its 10^6 to 10^9 Ω source resistance from external circuitry. Just such an amplifier is shown in Figure 12. The low input current of the AD795 allows the voltage error produced by the bias current and electrode resistance to be minimal. The use of guarding, shielding, high insulation resistance standoffs, and other such standard methods used to minimize leakage are all needed to maintain the accuracy of this circuit.

The slope of the pH probe transfer function, 50 mV per pH unit at room temperature, has a +3300 ppm/°C temperature coefficient. The buffer of Figure 12 provides an output voltage equal to 1 volt/pH unit. Temperature compensation is provided by resistor RT which is a special temperature compensation resistor, part number Q81, 1 kΩ, 1%, +3500 ppm/°C, available from Tel Labs Inc.

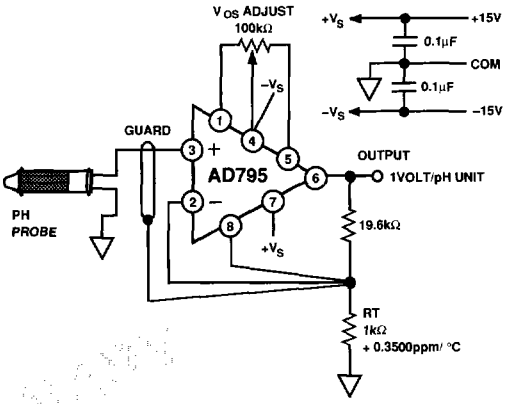

Figure 12. A pH Probe Amplifier

Circuit Board Notes

The AD795 is designed for through hole mount into PC boards. Maintaining picoampere level resolution in that environment requires a lot of care. Since both the printed circuit board and the amplifier's package have a finite resistance, the voltage difference between the amplifier's input pin and other pins (or traces on the PC board) will cause parasitic currents to flow into (or out of) the signal path. These currents can easily exceed the 1 pA input current level of the AD795 unless special precautions are taken. Two successful methods for minimizing leakage are: guarding the AD795's input lines and maintaining adequate insulation resistance.

Guarding the input lines by completely surrounding them with a metal conductor biased near the input lines' potential has two major benefits. First, parasitic leakage from the signal line is reduced, since the voltage between the input line and the guard is very low. Second, stray capacitance at the input terminal is minimized which in turn increases signal bandwidth. In the header or can package, the case of the AD795 is connected to Pin 8 so that it may be tied to the input potential (when operating as a follower) or tied to ground (when operating as an inverter). The AD795's positive input (Pin 3) is located next to the negative supply voltage pin (Pin 4). The negative input (Pin 2) is next to the balance adjust pin (Pin 1) which is biased at a potential close to that of the negative supply voltage. Note that any guard traces should be placed on *both* sides of the board. In addition, the input trace should be guarded along both of its edges, along its entire length.

Contaminants such as solder flux, on the board's surface and on the amplifier's package, can greatly reduce the insulation resistance and also increase the sensitivity to atmospheric humidity. Both the package and the board must be kept clean and dry. An effective cleaning procedure is to: first, swab the surface with high grade isopropyl alcohol, then rinse it with deionized water, and finally, bake it at 80°C for 1 hour. Note that if either polystyrene or polypropylene capacitors are used on the printed circuit board that a baking temperature of 70°C is safer, since both of these plastic compounds begin to melt at approximately +85°C.