ANALOG DEVICES

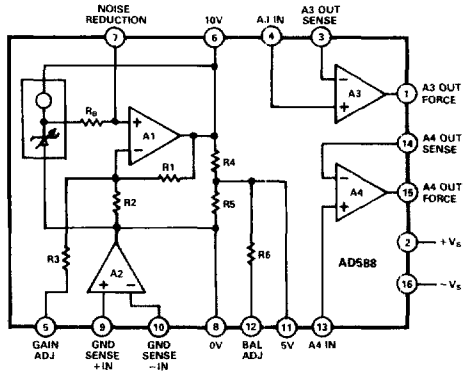
Ultra High Precision Voltage Reference

AD588

FEATURES

Ultra Low Drift – 1ppm/°C
Ultra Low Initial Error – 1mV
Pin-Programmable Output
+10V, +5V, ±5V Tracking, −5V, −10V
Flexible Output Force and Sense Terminals
High Impedance Ground Sense
Machine-Insertable DIP Packaging
Guaranteed Long-Term Stability – 25ppm/1000 hours

AD588 FUNCTIONAL BLOCK DIAGRAM



3

PRODUCT DESCRIPTION

The AD588 represents a major advance in the state-of-the-art in monolithic voltage references. It offers a combination of low initial error and low temperature drift previously found only in hybrid units at much higher cost. The AD588 uses a proprietary ion-implanted buried zener diode, and laser-wafer-drift trimming of high stability thin-film resistors to provide outstanding performance at low cost.

The AD588 includes the basic reference cell and three additional amplifiers which provide pin-programmable output ranges. The amplifiers are laser-trimmed for low offset and low drift and maintain the accuracy of the reference. The amplifiers are configured to allow Kelvin connections to the load and/or boosters for driving long lines or high-current loads while maintaining full accuracy.

The low initial error allows the AD588 to be used as a system reference in applications requiring 12-bit absolute accuracy. In such systems, the AD588 can provide a known voltage for system calibration in software and the low drift allows compensation for the drift of other components in a system. Manual system calibration and the cost of periodic recalibration can therefore be eliminated. Furthermore, the mechanical instability of a trimming potentiometer and the potential for improper calibration can be eliminated by using the AD588 and autocalibration software.

The AD588 is available in seven versions. The AD588JN, KN, and LN are specified for the 0 to +70°C temperature range and are packaged in a 16-pin plastic DIP. The AD588AD, BD, and CD grades are packaged in a 16-pin side-brazed ceramic DIP and are specified for the −25°C to +85°C industrial temperature range. The ceramic AD588SD and TD grades are specified for the full military/aerospace temperature range.

PRODUCT HIGHLIGHTS

1. The AD588 offers 12-bit absolute accuracy without any user adjustments. Optional fine-trim connections are provided for applications requiring higher precision. The fine-trimming does not alter the operating conditions of the zener or the buffer amplifiers and thus does not increase the temperature drift.
2. Long-term stability is excellent and the LN, CD, and TD versions are 100% tested and guaranteed for 25 parts-per-million stability in a 1000-hour period.
3. Output noise of the AD588 is very low – typically 10μV p-p. A pin is provided for additional noise filtering using an external capacitor.
4. A precision ±5V tracking mode with Kelvin output connections is available with no external components. Tracking error is less than one millivolt and a fine-trim is available for applications requiring exact symmetry between the +5V and −5V outputs.
5. Pin strapping capability allows configuration of a wide variety of outputs: ±5V, +5V & +10V, −5V & −10V dual outputs or +5V, −5V, +10V, −10V single outputs.

SPECIFICATIONS (typical @ +25°C and V_S = ±15V unless otherwide noted)

	AD588JN/AD/SD/TD			AD588KN/LN/BD/CD			
	Min	Typ	Max	Min	Typ	Max	Units
OUTPUT VOLTAGE ERROR							
+10V, −10V Outputs	−3		3	−1		+1	mV
+5V, −5V Outputs	−1.5		1.5	−0.5		+0.5	mV
OUTPUT VOLTAGE DRIFT							
25 to T_{min} or T_{max}	−3		3	−1		+1	ppm/°C
25 to T_{min} or T_{max} (T Grade)	−5		5				ppm/°C
LINE REGULATION							
+10V Output,							
+11.4V<+V_S<+18V	−100		100	−100		100	μV/V
−10V Output,							
−18V<−V_S<−11.4V	−100		100	−100		100	μV/V
LOAD REGULATION							
+10V, −10V Outputs,							
0<I_{OUT}<10mA	−100		100	−100		100	μV/mA
QUIESCENT CURRENT		7	10		7	10	mA
OUTPUT NOISE (Any Output)							
0.1 to 10Hz		10			10		μV p-p
Spectral Density, 100Hz		100			100		nV/√Hz
LONG-TERM STABILITY (@ +25°C)							
J, K, A, B, S Grades		25			25		ppm/1000hr
L, C, T Grades			25			25	ppm/1000hr
±5V TRACKING MODE							
Symmetry Error	−1.5		1.5	−0.5		+0.5	mV
BUFFER AMPLIFIERS							
Offset Voltage		100			100		μV
Bias Current		20			20		nA
Open Loop Gain		110			110		dB
Output Current A3, A4	−10		+10	−10		+10	mA
SHORT-CIRCUIT CURRENT		20			20		mA
TEMPERATURE RANGE							
Specified Performance							
J, K, L Grades	0		+70	0		+70	°C
A, B, C Grades	−25		+85	−25		+85	°C
S, T Grades	−55		+125				°C

NOTE
Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

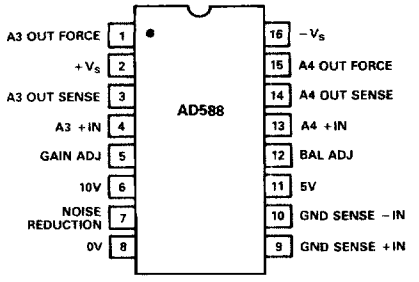
ABSOLUTE MAXIMUM RATINGS

$+V_S$ to $-V_S$	36V
Power Dissipation (+25°C)	
D Package	600mW
N Package	600mW
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10sec)	300°C
Package Thermal Resistance	
D (θ_{jn}/θ_{jc})	90/25°C/W
N (θ_{jn}/θ_{jc})	137/53°C/W
Output Protection: All outputs safe if shorted to ground	

ORDERING GUIDE

Part Number	Initial Error	Temperature Coefficient	Temperature Range °C	Package
AD588JN	3mV	3ppm/°C	0 to +70	Plastic
AD588KN	1mV	1ppm/°C	0 to +70	Plastic
AD588LN	1mV	1ppm/°C	0 to +70	Plastic
AD588AD	3mV	3ppm/°C	−25 to +85	Ceramic
AD588BD	1mV	1ppm/°C	−25 to +85	Ceramic
AD588CD	1mV	1ppm/°C	−25 to +85	Ceramic
AD588SD	3mV	3ppm/°C	−55 to +125	Ceramic
AD588TD	3mV	5ppm/°C	−55 to +125	Ceramic

AD588 PIN CONFIGURATION



Theory of Operation

The AD588 consists of a buried zener diode reference, amplifiers used to provide pin programmable output ranges, and associated thin film resistors as shown in the block diagram of Figure 1. The temperature compensation circuitry provides the device with a temperature coefficient of 1ppm/°C or less.

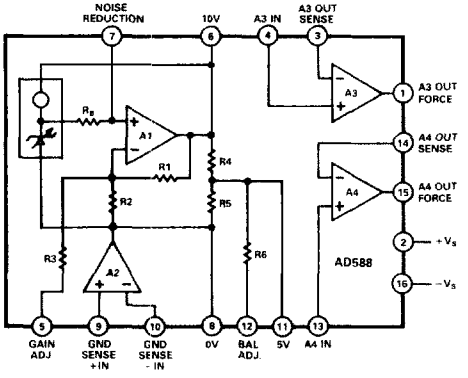


Figure 1. AD588 Functional Block Diagram

Amplifier A1 performs several functions. A1 primarily acts to amplify the zener voltage from 6.5V to the required 10V output. In addition, A1 also provides for external adjustment of the 10V output through pin 5, the GAIN ADJUST. Using the bias compensation resistor between the zener output and the non-inverting input to A1, a capacitor can be added at the NOISE REDUCTION pin (pin 7) to form a low pass filter and reduce the noise contribution of the zener to the circuit. Two matched thin film resistors (R4 & R5) divide the 10V output in half. The 5V pin (pin 11) provides access to this voltage and pin 12 (BALANCE ADJUST) can be used for fine adjustment of this division.

Ground sensing for the circuit is provided by amplifier A2. The non-inverting input (pin 9) senses the system ground which will be transferred to the point on the circuit where the inverting input (pin 10) is connected. This may be pin 6, 8 or 11. The output of A2 drives pin 8 to the appropriate voltage. Thus, if pin 10 is connected to pin 8, the 0V pin will be the same voltage as the system ground. Alternatively, if pin 10 is connected to the 5V pin, it will be ground and pin 6 and pin 8 will be +5V and −5V respectively.

Amplifiers A3 and A4 are internally compensated and are used to buffer the voltages at pins 6, 8, and 11 as well as to provide a full Kelvin output. Thus, the AD588 has a full Kelvin capability by providing the means to sense a system ground and provide forced and sensed outputs referenced to that ground.

Applying the AD588

The AD588 may be configured in a number of different ways to provide dual reference outputs (+5V and +10V, +5V and −5V, or −5V and −10V) or any of the following single reference outputs: +5V, +10V, −5V or −10V. The various options are set up by using the inverting input (pin 10) of A2. Table I details the appropriate pin connections for each output range.

Single Outputs

Pin 9 should be connected to the system ground and power is applied to pins 2 and 16. Figure 2 and Table I show the connections for each of the options. The unused output amplifiers A3 and/or A4 should have the output force and sense pins connected and their input tied to pin 6 or pin 8.

Dual Outputs

With power applied to pins 2 and 16 and pin 9 connected to the system ground, the AD588 will produce the appropriate output ranges when connected as shown in Table I and Figure 2. Depending upon the voltages required, the unbuffered outputs are available at pins 6, 8 and 11. Either signal may be buffered by amplifiers A3 and A4. At this point, the GAIN ADJUST and BALANCE ADJUST pins may be used as described in the CALIBRATION section. If desired, two outputs of the same voltage may be obtained by connecting both output buffers to the appropriate output pins. This is shown in Table I.

RANGE	CONNECT PIN 10 TO PIN:	UNBUFFERED OUTPUT ON PINS −10V	−5V	0V	+5V	+10V	BUFFERED OUTPUT CONNECTIONS	BUFFERED OUTPUT ON PINS −10V	−5V	0V	+5V	+10V
SINGLE OUTPUTS												
+5V or +10V	8	–	–	8	13	6	11-13 & 14-15 or 6-4 & 3-1	–	–	–	15	–
								–	–	–	–	1
−5V or +5V	11	–	8	11	6	–	8-13 & 14-15 or 6-4 & 3-1	–	15	–	–	–
								–	–	–	1	–
−5V or −10V	6	8	11	6	–	–	11-13 & 14-15 or 8-4 & 3-1	–	15	–	–	–
								1	–	–	–	–
DUAL OUTPUTS												
+5V	8	–	–	–	11	–	11-13 & 14-15	–	–	–	15	–
+10V		–	–	–	–	6	6-4 & 3-1	–	–	–	–	1
+5V	11	–	–	–	6	–	6-4 & 3-1	–	–	–	1	–
−5V		–	8	–	–	–	8-13 & 14-15	–	15	–	–	–
−5V	6	–	11	–	–	–	11-4 & 3-1	–	1	–	–	–
−10V		8	–	–	–	–	8-13 & 14-15	15	–	–	–	–
+5V	8	–	–	–	11	–	11-13 & 14-15	–	–	–	15	–
+5V		–	–	–	11	–	11-4 & 3-1	–	–	–	1	–
+10V	8	–	–	–	–	6	6-13 & 14-15	–	–	–	–	15
+10V		–	–	–	–	6	6-4 & 3-1	–	–	–	–	1
−5V	6	–	11	–	–	–	11-4 & 3-1	–	1	–	–	–
−5V		–	11	–	–	–	11-13 & 14-15	–	15	–	–	–
−10V	6	8	–	–	–	–	8-4 & 3-1	1	–	–	–	–
−10V		8	–	–	–	–	8-13 & 14-15	15	–	–	–	–

Table I. AD588 Connections

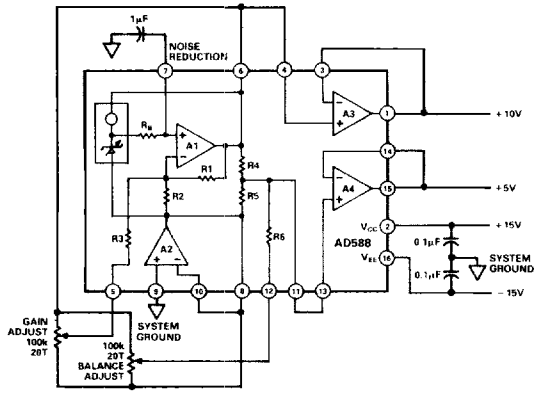


Figure 2a. +10V and +5V Outputs

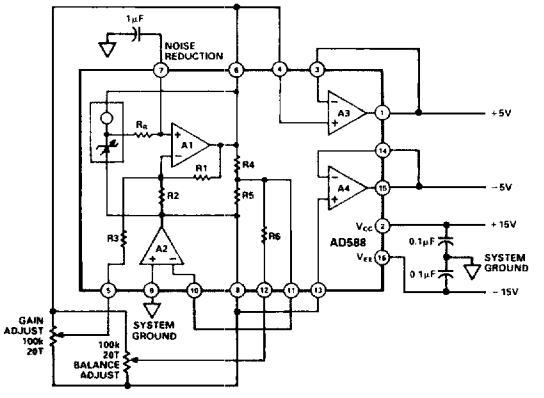


Figure 2b. +5V and -5V Outputs

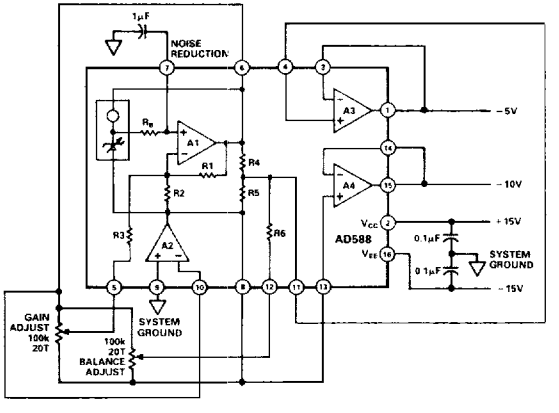


Figure 2c. -5V and -10V Outputs

CALIBRATION

Generally, the AD588 will meet the requirements of a precision system without additional adjustment. Initial output voltage error of 1mV and output noise specs of 10μV p-p allow for accuracies of 12-16 bits. However, in applications where an even greater level of accuracy is required, additional calibration may be called for. Provision for trimming has been made through the use of the GAIN ADJUST and BALANCE ADJUST pins (pins 5 and 12 respectively).

Gain adjustment can be accomplished by using a 100k, 20 turn potentiometer connected between pins 6 and 8. The wiper should be connected to GAIN ADJUST pin 5 as shown in Figures 2a, b, c. The typical adjustment range of this setup is −3.5mV to +7.5mV with a resolution of approximately 550μV/turn.

Trimming the AD588 introduces no additional errors over temperature so a precision potentiometer is not required.

For the ±5V range, an additional adjustment, the BALANCE trim, may be required. Adjustments of these outputs independently control the gain (pin 6 – pin 8) and the symmetry or balance of the output. Gain adjustment is identical to the one described above. The balance adjustment also uses a 100K, 20 turn potentiometer connected between pins 6 and 8. The tap is connected to pin 12, BALANCE ADJUST, and provides a range of ±4.5mV with a resolution of 450μV/turn.

For single output voltage ranges, or in cases when BALANCE ADJUST is not required, pin 12 should be connected to pin 11. If GAIN ADJUST is not required, pin 5 should be left floating.

NOISE REDUCTION

The noise generated by the AD588 is typically less than 10μV p-p over the 0.1 to 10Hz band. Noise in a 1MHz bandwidth is approximately 800μV p-p. The dominant source of this noise is the buried zener which contributes approximately 100nV/$\sqrt{\text{Hz}}$. In comparison, the op amp's contribution is negligible.

If further noise reduction is desired, an optional capacitor may be added to the NOISE REDUCTION pin. This will form a low pass filter on the output of the zener cell. A 1μF capacitor will have a 3dB point at 40Hz and will reduce the high frequency 1MHz noise to about 200μV p-p. Figures 2a, b, and c show a noise reduction capacitor connected. The NOISE REDUCTION function must not be used when configuring the device when pin 10 is connected to pin 6 (−10V output).