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# High Precision 2.5 V IC Reference

## AD580\*

### FEATURES

Laser Trimmed to High Accuracy:  $2.500\text{ V} \pm 0.4\%$

3-Terminal Device: Voltage In/Voltage Out

Excellent Temperature Stability:  $10\text{ ppm}/^\circ\text{C}$  (AD580M, U)

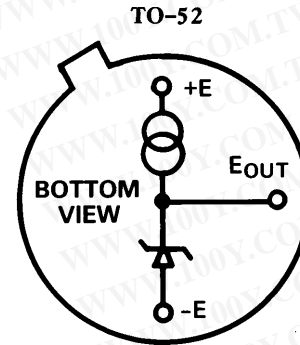
Excellent Long-Term Stability:  $250\text{ }\mu\text{V}$  ( $25\text{ }\mu\text{V}/\text{Month}$ )

Low Quiescent Current:  $1.5\text{ mA max}$

Small, Hermetic IC Package: TO-52 Can

MIL-STD-883 Compliant Versions Available

### FUNCTIONAL BLOCK DIAGRAM



### PRODUCT DESCRIPTION

The AD580 is a three-terminal, low cost, temperature compensated, bandgap voltage reference which provides a fixed 2.5 V output for inputs between 4.5 V and 30 V. A unique combination of advanced circuit design and laser-wafer trimmed thin-film resistors provide the AD580 with an initial tolerance of  $\pm 0.4\%$ , a temperature stability of better than  $10\text{ ppm}/^\circ\text{C}$  and long-term stability of better than  $250\text{ }\mu\text{V}$ . In addition, the low quiescent current drain of  $1.5\text{ mA max}$  offers a clear advantage over classical Zener techniques.

The AD580 is recommended as a stable reference for all 8-, 10- and 12-bit D-to-A converters that require an external reference. In addition, the wide input range of the AD580 allows operation with 5 volt logic supplies making the AD580 ideal for digital panel meter applications or whenever only a single logic power supply is available.

The AD580J, K, L and M are specified for operation over the  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  temperature range; the AD580S, T and U are specified for operation over the extended temperature range of  $-55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

### PRODUCT HIGHLIGHTS

1. Laser-trimming of the thin-film resistors minimizes the AD580 output error. For example, the AD580L output tolerance is  $\pm 10\text{ mV}$ .
2. The three-terminal voltage in/voltage out operation of the AD580 provides regulated output voltage without any external components.
3. The AD580 provides a stable 2.5 V output voltage for input voltages between 4.5 V and 30 V. The capability to provide a stable output voltage using a 5-volt input makes the AD580 an ideal choice for systems that contain a single logic power supply.
4. Thin-film resistor technology and tightly controlled bipolar processing provide the AD580 with temperature stabilities to  $10\text{ ppm}/^\circ\text{C}$  and long-term stability better than  $250\text{ }\mu\text{V}$ .
5. The low quiescent current drain of the AD580 makes it ideal for CMOS and other low power applications.
6. The AD580 is available in versions compliant with MIL-STD-883. Refer to the Analog Devices Military Products Databook or current AD580/883B data sheet for detailed specifications.

\*Protected by Patent Nos. 3,887,863; RE30,586.

### REV. A

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# AD580—SPECIFICATIONS (@ $E_{IN} = +15\text{ V}$ and $+25^\circ\text{C}$ )

Model	AD580J			AD580K			AD580L			AD580M			Units
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
OUTPUT VOLTAGE TOLERANCE (Error from Nominal 2.500 Volt Output)			$\pm 75$			$\pm 25$			$\pm 10$			$\pm 10$	mV
OUTPUT VOLTAGE CHANGE $T_{MIN}$ to $T_{MAX}$			15 85			7 40			4.3 25			1.75 10	mV ppm/ $^\circ\text{C}$
LINE REGULATION $7\text{ V} \leq V_{IN} \leq 30\text{ V}$ $4.5\text{ V} \leq V_{IN} \leq 7\text{ V}$		1.5 0.3	<b>6</b> <b>3</b>		1.5 0.3	<b>4</b> <b>2</b>			2 1			2 1	mV mV
LOAD REGULATION $\Delta I = 10\text{ mA}$			<b>10</b>			<b>10</b>			<b>10</b>			<b>10</b>	mV
QUIESCENT CURRENT		1.0	<b>1.5</b>		1.0	<b>1.5</b>		1.0	<b>1.5</b>		1.0	<b>1.5</b>	mA
NOISE (0.1 Hz to 10 Hz)			8			8			8			8	$\mu\text{V}$ (p-p)
STABILITY Long Term Per Month			250 25			250 25			250 25			250 25	$\mu\text{V}$ $\mu\text{V}$
TEMPERATURE PERFORMANCE Specified Operating Storage	0 -55 -65		+70 <b>+125</b> <b>+175</b>	0 -55 -65		+70 <b>+125</b> <b>+175</b>	0 -55 -65		+70 <b>+125</b> <b>+175</b>	0 -55 -65		+70 <b>+125</b> <b>+175</b>	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$
PACKAGE OPTION* TO-52 (H-03A)			AD580JH			AD580KH			AD580LH			AD580MH	

Model	AD580S			AD580T			AD580U			Units
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
OUTPUT VOLTAGE TOLERANCE (Error from Nominal 2.500 Volt Output)			$\pm 25$			$\pm 10$			$\pm 10$	mV
OUTPUT VOLTAGE CHANGE $T_{MIN}$ to $T_{MAX}$			25 55			11 25			4.5 10	mV ppm/ $^\circ\text{C}$
LINE REGULATION $7\text{ V} \leq V_{IN} \leq 30\text{ V}$ $4.5\text{ V} \leq V_{IN} \leq 7\text{ V}$		1.5 0.3	<b>6</b> <b>3</b>			2 1			2 1	mV mV
LOAD REGULATION $\Delta I = 10\text{ mA}$			<b>10</b>			<b>10</b>			<b>10</b>	mV
QUIESCENT CURRENT		1.0	<b>1.5</b>		1.0	<b>1.5</b>		1.0	<b>1.5</b>	mA
NOISE (0.1 Hz to 10 Hz)			8			8			8	$\mu\text{V}$ (p-p)
STABILITY Long Term Per Month			250 25			250 25			250 25	$\mu\text{V}$ $\mu\text{V}$
TEMPERATURE PERFORMANCE Specified Operating Storage	-55 -55 -65		+125 <b>+150</b> <b>+175</b>	-55 -55 -65		+125 <b>+150</b> <b>+175</b>	-55 -55 -65		+125 <b>+150</b> <b>+175</b>	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$
PACKAGE OPTION* TO-52 (H-03A)			AD580SH			AD580TH			AD580UH	

## NOTES

\*H = Metal Can.

Specifications subject to change without notice.

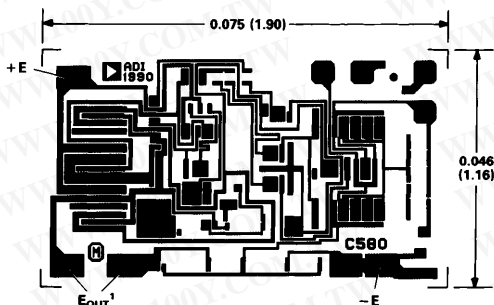
Specifications shown in **boldface** are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in **boldface** are tested on all production units.

**ABSOLUTE MAXIMUM RATINGS**

Input Voltage	40 V
Power Dissipation @ +25°C	
Ambient Temperature	350 mW
Derate above +25°C	2.8 mW/°C
Lead Temperature (Soldering 10 sec)	+300°C
Thermal Resistance	
Junction-to-Case	100°C
Junction-to-Ambient	360°C/W

**AD580 CHIP DIMENSIONS AND PAD LAYOUT**

Dimensions shown in inches and (mm).



NOTE  
BOTH E<sub>OUT</sub> PADS MUST BE CONNECTED TO THE OUTPUT.

The AD580 is also available in chip form. Consult the factory for specifications and applications information.

**THEORY OF OPERATION**

The AD580 family (AD580, AD581, AD584, AD589) uses the “bandgap” concept to produce a stable, low temperature coefficient voltage reference suitable for high accuracy data acquisition components and systems. The device makes use of the underlying physical nature of a silicon transistor base-emitter voltage in the forward-biased operating region. All such transistors have approximately a -2 mV/°C temperature coefficient, unsuitable for use directly as a low TC reference; however, extrapolation of the temperature characteristic of any one of these devices to absolute zero (with emitter current proportional to absolute temperature) reveals that it will go to a V<sub>BE</sub> of 1.205 volts at 0K, as shown in Figure 1. Thus, if a voltage could be developed with an opposing temperature coefficient to sum with V<sub>BE</sub> to total 1.205 volts, a zero-TC reference would result and operation from a single, low voltage supply would be possible. The AD580 circuit provides such a compensating voltage, V<sub>1</sub> in Figure 2, by driving two transistors at different current densities and amplifying the resulting V<sub>BE</sub> difference (ΔV<sub>BE</sub>—which now has a positive TC); the sum (V<sub>z</sub>) is then buffered and amplified up to 2.5 volts to provide a usable reference-voltage output. Figure 3 is the schematic diagram of the AD580.

The AD580 operates as a three-terminal reference, which means that no additional components are required for biasing or current setting. The connection diagram, Figure 4 is quite simple.

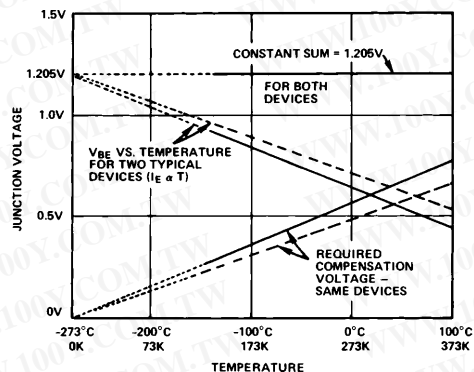


Figure 1. Extrapolated Variation of Base-Emitter Voltage with Temperature ( $I_E \propto T$ ), and Required Compensation, Shown for Two Different Devices

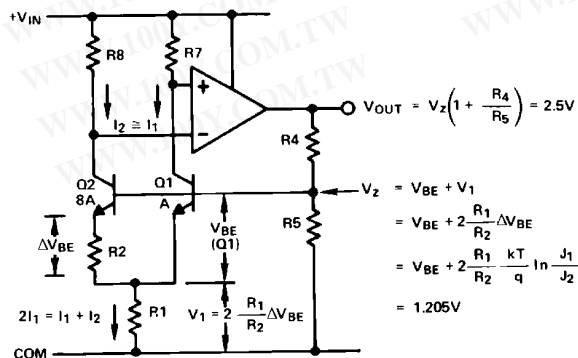


Figure 2. Basic Bandgap-Reference Regulator Circuit

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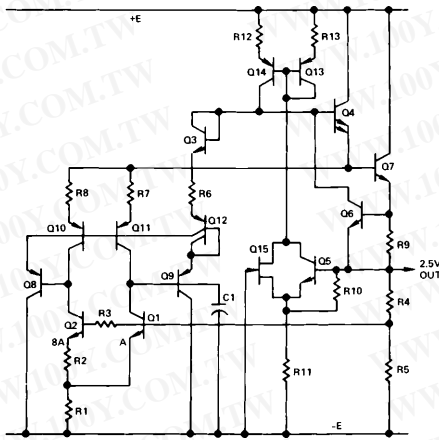


Figure 3. AD580 Schematic Diagram

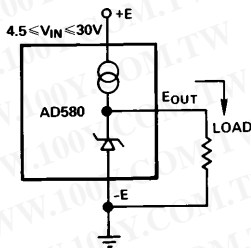


Figure 4. AD580 Connection Diagram

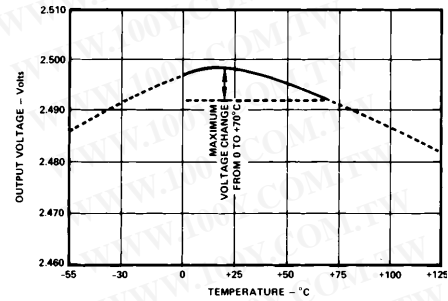


Figure 5. Typical AD580K Output Voltage vs. Temperature

The AD580M guarantees a maximum deviation of 1.75 mV over the 0°C to +70°C temperature range. This can be shown to be equivalent to 10 ppm/°C average maximum; i.e.,

$$\frac{1.75 \text{ mV max}}{70^\circ\text{C}} \times \frac{1}{2.5\text{V}} = 10 \text{ ppm}/^\circ\text{C max average}$$

The AD580 typically exhibits a variation of 1.5 mV over the power supply range of 7 volts to 30 volts. Figure 6 is a plot of AD580 line rejection versus frequency.

### NOISE PERFORMANCE

Figure 7 represents the peak-to-peak noise of the AD580 from 1 Hz (3 dB point) to a 3 dB high end shown on the horizontal axis. Peak-to-peak noise from 1 Hz to 1 MHz is approximately 600  $\mu\text{V}$ .

### VOLTAGE VARIATION VS. TEMPERATURE

Some confusion exists in the area of defining and specifying reference voltage error over temperature. Historically, references are characterized using a maximum deviation per degree Centigrade; i.e., 10 ppm/°C. However, because of the inconsistent nonlinearities in Zener references (butterfly or "S" type characteristics), most manufacturers use a maximum limit error band approach to characterize their references. This technique measures the output voltage at 3 to 5 different temperatures and guarantees that the output voltage deviation will fall within the guaranteed error band at these discrete temperatures. This approach, of course, makes no mention or guarantee of performance at any other temperature within the operating temperature range of the device.

The consistent Voltage vs. Temperature performance of a typical AD580 is shown in Figure 5. Note that the characteristic is quasi-parabolic, not the possible "S" type characteristics of classical Zener references. This parabolic characteristic permits a maximum output deviation specification over the device's full operating temperature range, rather than just at 3 to 5 discrete temperatures.

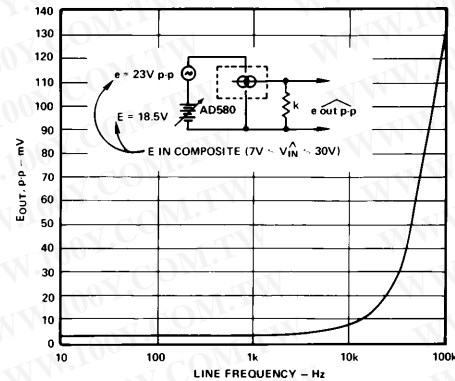


Figure 6. AD580 Line Rejection Plot

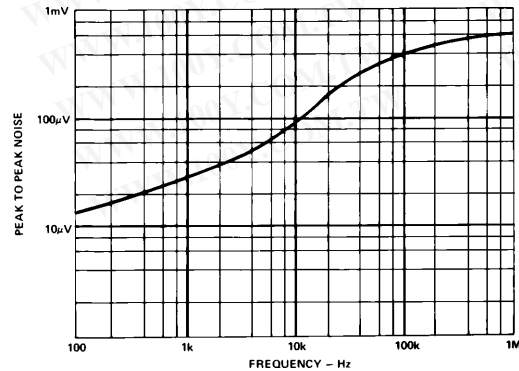


Figure 7. Peak-to-Peak Output Noise vs. Frequency

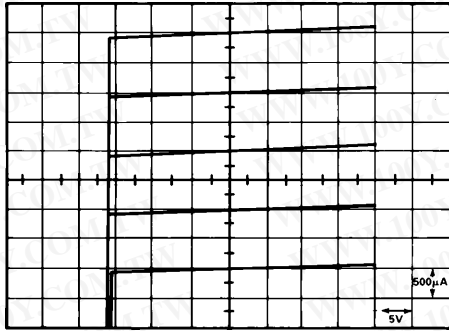


Figure 8. Input Current vs. Input Voltage (Integral Loads)

**THE AD580 AS A CURRENT LIMITER**

The AD580 represents an excellent alternative to current limiter diodes which require factory-selection to achieve a desired current. This approach often results in temperature coefficients of 1%/°C. The AD580 approach is not limited to a specially selected factory set current limit; it can be programmed from 1 mA to 10 mA with the insertion of a single external resistor. The approximate temperature coefficient of current limit for the AD580 used in this mode is 0.13%/°C for  $I_{LIM} = 1$  mA and 0.01%/°C for  $I_{LIM} = 13$  mA (see Figure 9). Figure 8 displays the high output impedance of the AD580 used as a current limiter for  $I_{LIM} = 1, 2, 3, 4, 5$  mA.

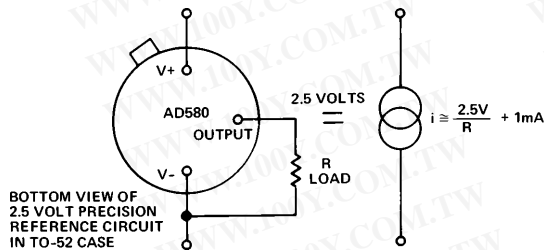


Figure 9. A Two-Component Precision Current Limiter

**THE AD580 AS A LOW POWER, LOW VOLTAGE PRECISION REFERENCE FOR DATA CONVERTERS**

The AD580 has a number of features that make it ideally suited for use with A/D and D/A data converters used in complex microprocessor-based systems. The calibrated 2.500 volt output minimizes user trim requirements and allows operation from a single low voltage supply. Low power consumption (1 mA quiescent current) is commensurate with that of CMOS-type devices, while the low cost and small package complements the decreasing cost and size of the latest converters.

Figure 10 shows the AD580 used as a reference for the AD7542 12-bit CMOS DAC with complete microprocessor interface. The AD580 and the AD7542 are specified to operate from a single 5 volt supply; this eliminates the need to provide a +15 volt power supply for the sole purpose of operating a reference. The AD7542 includes three 4-bit data registers, a 12-bit DAC register, and address decoding logic; it may thus be interfaced directly to a 4-, 8- or 16-bit data bus. Only 8 mA of quiescent current from the single +5 volt supply is required to operate the AD7542 which is packaged in a small 16-pin DIP. The AD544 output amplifier is also low power, requiring only 2.5 mA quiescent current. Its laser-trimmed offset voltage preserves the  $\pm 1/2$  LSB linearity of the AD7542KN without user trims and it typically settles to  $\pm 1/2$  LSB in less than 3  $\mu$ s. It will provide the 0 volt to -2.5 volt output swing from  $\pm 5$  volt supplies.

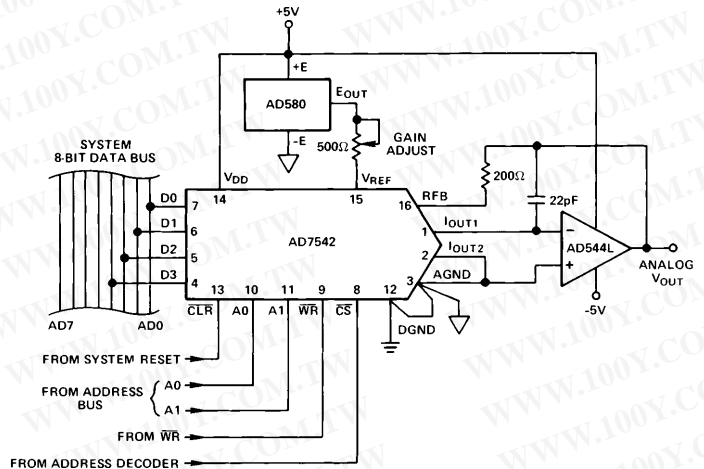


Figure 10. Low Power, Low Voltage Reference for the AD7542 Microprocessor-Compatible 12-Bit DAC

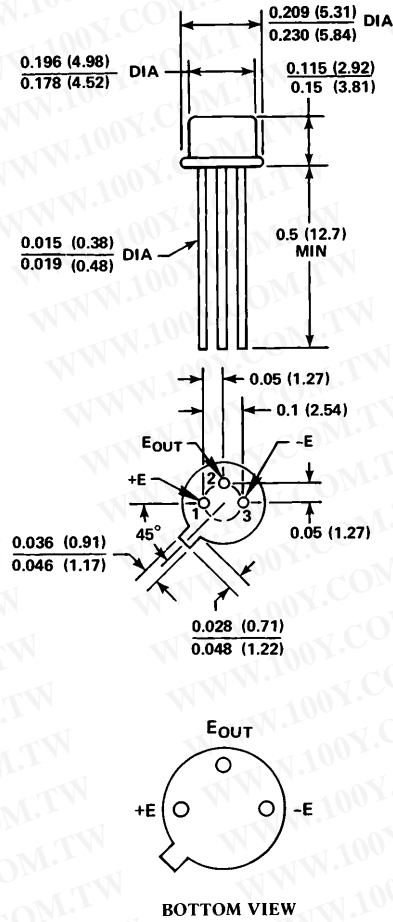
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## OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

### TO-52 Package



C549a-4-8/85

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