EL8188

Micropower Single Supply Rail-to-Rail Input-Output Precision Op Amp

FN7467
Rev 7.00
February 24, 2011

The EL8188 is a precision low power, operational amplifier. The device is optimized for single supply operation between 2.4V to 5.5V. This enables operation from one lithium cell or two Ni-Cd batteries. The input range includes both positive and negative rail.

The EL8188 draws minimal supply current (55µA) while meeting excellent DC-accuracy, noise, and output drive specifications.

Ordering Information

PART NUMBER	PART MARKING	TEMP RANGE (°C)	PACKAGE (Pb-Free)	PKG. DWG. #
EL8188FIZ-T7* (Note 2)	188Z	-40 to +125	6 Ld WLCSP (1.5mmx1.0mm)	W3x2.6C
EL8188FWZ-T7A* (Notes 1, 3)	BBYA	-40 to +125	6 Ld SOT-23	P6.064A
EL8188FWZ-T7* (Notes 1, 3)	BBYA	-40 to +125	6 Ld SOT-23	P6.064A
EL8188ISZ (Note 1)	8188ISZ	-40 to +125	8 Ld SOIC	M8.15E
EL8188ISZ-T7* (Note 1)	8188ISZ	-40 to +125	8 Ld SOIC	M8.15E
EL8188ISZ-T13* (Note 1)	8188ISZ	-40 to +125	8 Ld SOIC	M8.15E

*Please refer to TB347 for details on reel specifications.

NOTES:

1. These Intersil Pb-free plastic packaged products employ special Pb-free material sets, molding compounds/die attach materials, and 100% matte tin plate plus anneal (e3 termination finish, which is RoHS compliant and compatible with both SnPb and Pb-free soldering operations). Intersil Pb-free products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020
2. These Intersil Pb-free WLCSP and BGA packaged products products employ special Pb-free material sets; molding compounds/die attach materials and SnAgCu - e1 solder ball terminals, which are RoHS compliant and compatible with both SnPb and Pb-free soldering operations. Intersil Pb-free WLCSP and BGA packaged products are MSL classified at Pb-free peak reflow temperatures that meet or exceed the Pb-free requirements of IPC/JEDEC J STD-020.
3. The part marking is located on the bottom of the part.

Features

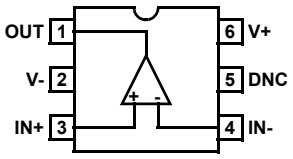
- Typical 55µA Supply Current
- 1mV Max Offset Voltage
- Typical 1pA Input Bias Current
- 266kHz Gain-bandwidth Product
- Single Supply Operation Between 2.4V to 5.5V
- Rail-to-rail Input and Output
- Ground Sensing
- Output Sources and Sinks 26mA Load Current
- Pb-free (RoHS compliant)

Applications

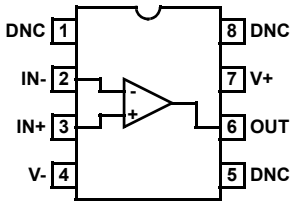
- Battery - or Solar-powered Systems
- 4mA to 20mA Current Loops
- Handheld Consumer Products
- Medical Devices
- Thermocouple Amplifiers
- Photodiode Pre-amps
- pH Probe Amplifiers

Pinouts

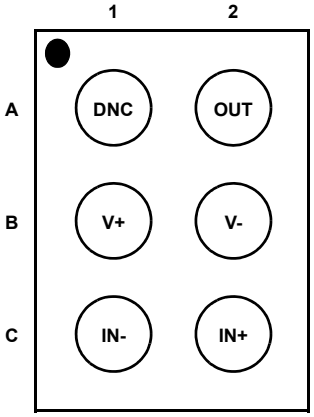
EL8188
(6 LD SOT-23)
TOP VIEW



EL8188
(8 LD SO)
TOP VIEW



EL8188
(6 LD WLCSP)
TOP VIEW



Absolute Maximum Ratings (T_A = +25°C)

Supply Voltage (V_S) and Pwr-up Ramp Rate 5.75V, 1V/µs
Differential Input Voltage 0.5V
Current into IN+, IN-. 5mA
Input Voltage . . . . . V_- -0.5V to V_+ +0.5V
ESD Tolerance
Human Body Model 3kV
Machine Model 300V

Thermal Information

Thermal Resistance	θ_{JA} (°C/W)
6 Ld SOT Package	230
6 Ld WLCSP Package	130
8 Ld SOIC Package	125

Ambient Operating Temperature Range . . . . . -40°C to +125°C
Storage Temperature Range . . . . . -65°C to +150°C
Operating Junction Temperature . . . . . +125°C
Pb-free reflow profile . . . . . .see link below
http://www.intersil.com/pbfree/Pb-FreeReflow.asp

CAUTION: Do not operate at or near the maximum ratings listed for extended periods of time. Exposure to such conditions may adversely impact product reliability and result in failures not covered by warranty.

IMPORTANT NOTE: All parameters having Min/Max specifications are guaranteed. Typical values are for information purposes only. Unless otherwise noted, all tests are at the specified temperature and are pulsed tests, therefore: $T_J = T_C = T_A$

Electrical Specifications

V_+ = 5V, V_- = 0V, V_{CM} = 2.5V, V_O = 2.5V, T_A = +25°C unless otherwise specified. **Boldface limits** apply over the operating temperature range, **-40°C to +125°C**

PARAMETER	DESCRIPTION	TEST CONDITIONS	MIN (Note 4)	TYP	MAX (Note 4)	UNIT
V_{OS}	Input Offset Voltage	SOT-23	-1	0.05	+1	mV
			-1.5		**+1.5**	mV
		WLCSP	**-1.5**		**+1.5**	mV
$\frac{\Delta V_{OS}}{\Delta Time}$	Long Term Input Offset Voltage Stability			3		µV/Mo
$\frac{\Delta V_{OS}}{\Delta T}$	Input Offset Drift vs Temperature			1.1		µV/°C
I_B	Input Bias Current (See Figure 20)		-25	1	25	pA
			-600		**600**	pA
e_N	Input Noise Voltage Peak-to-Peak	f = 0.1Hz to 10Hz		2.8		μV_{P-P}
	Input Noise Voltage Density	f_O = 1kHz		48		$nV/\sqrt{Hz}$
i_N	Input Noise Current Density	f_O = 1kHz		0.15		$pA/\sqrt{Hz}$
CMIR	Input Voltage Range	Guaranteed by CMRR test	0		5	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0V to 5V	80	100		dB
			75			dB
PSRR	Power Supply Rejection Ratio	V_S = 2.4V to 5.5V	80	100		dB
			80			dB
A_{VOL}	Large Signal Voltage Gain	V_O = 0.5V to 4.5V, R_L = 100kΩ to (V_+ + V_-)/2	100	400		V/mV
			100			V/mV
V_{OUT}	Maximum Output Voltage Swing SOT-23	V_{OL}; Output low, R_L = 100kΩ to (V_+ + V_-)/2		3	**10**	mV
		V_{OL}; Output low, R_L = 1kΩ to (V_+ + V_-)/2		130	250	mV
					350	mV
		V_{OH}; Output high, R_L = 100kΩ to (V_+ + V_-)/2	4.994	4.9975		V
			4.994			V
		V_{OH}; Output high, R_L = 1kΩ to (V_+ + V_-)/2	4.750	4.875		V
			4.7			V

Electrical Specifications V_+ = 5V, V_- = 0V, V_{CM} = 2.5V, V_O = 2.5V, T_A = +25°C unless otherwise specified. **Boldface limits** apply over the operating temperature range, **-40°C to +125°C (Continued)**

PARAMETER	DESCRIPTION	TEST CONDITIONS	MIN (Note 4)	TYP	MAX (Note 4)	UNIT
V_{OUT}	Maximum Output Voltage Swing WLCSP	V_{OL}; Output low, R_L = 100kΩ to (V+ + V-)/2		3	**10**	mV
		V_{OL}; Output low, R_L = 1kΩ to (V+ + V-)/2		130	250	mV
					350	mV
		V_{OH}; Output high, R_L = 100kΩ to (V+ + V-)/2	**4.991**	4.997		V
		V_{OH}; Output high, R_L = 1kΩ to (V+ + V-)/2	4.750	4.875		V
			4.7			V
SR	Slew Rate		0.1	0.15	0.19	V/µs
			0.07		**0.25**	V/µs
GBWP	Gain Bandwidth Product	f_O = 100kHz		266		kHz
$I_{S, ON}$	Supply Current, Enabled	SOT-23	35	55	75	µA
			30		**85**	µA
		WLCSP	45	65	85	µA
			40		**95**	µA
I_{SC}^+	Short Circuit Output Current	R_L = 10Ω to opposite supply	23	31		mA
			18			mA
I_{SC}^-	Short Circuit Output Current	R_L = 10Ω to opposite supply	20	26		mA
			15			mA
V_S	Supply Voltage	Guaranteed by PSRR	2.4		5.5	V
			2.4		**5.5**	V

NOTE:

4. .Compliance to datasheet limits is assured by one or more methods: production test, characterization and/or design.

Typical Performance Curves $V_S = \pm 2.5V$, $T_A = +25°C$, Unless Otherwise Specified

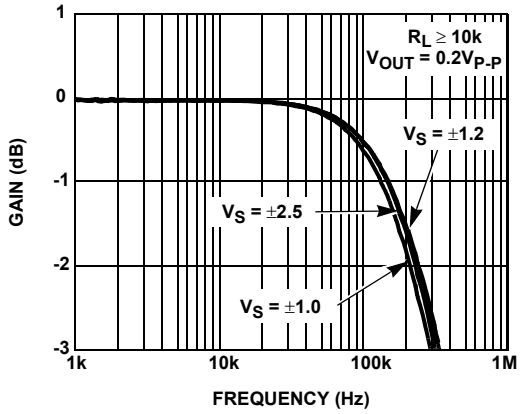


FIGURE 1. UNITY GAIN FREQUENCY RESPONSE at VARIOUS SUPPLY VOLTAGES

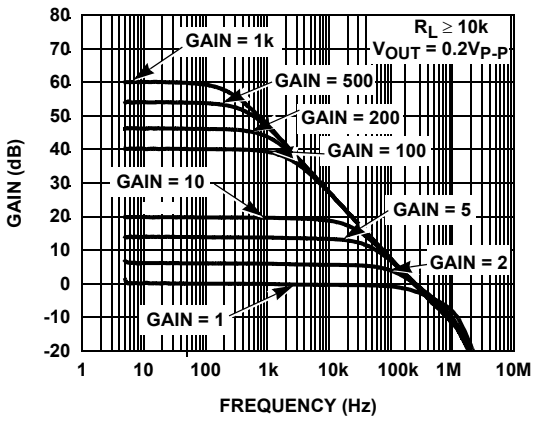


FIGURE 2. FREQUENCY RESPONSE at VARIOUS CLOSED LOOP GAINS

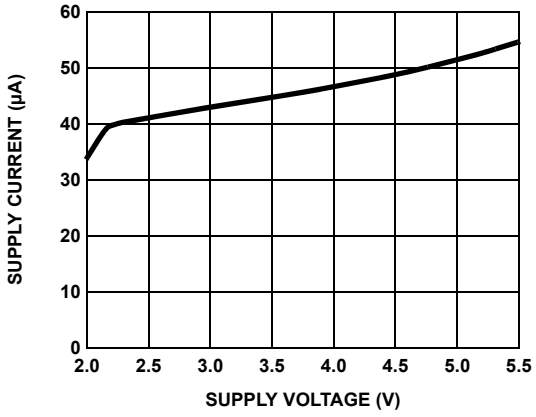


FIGURE 3. SUPPLY CURRENT vs SUPPLY VOLTAGE

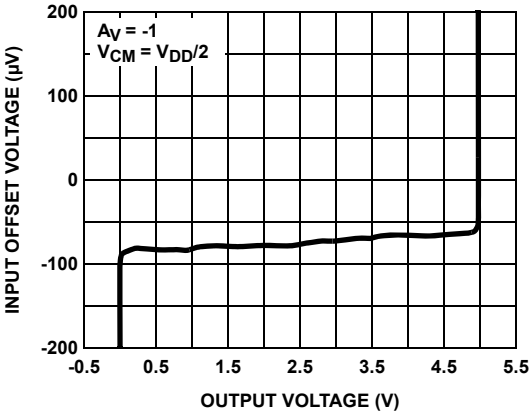


FIGURE 4. INPUT OFFSET VOLTAGE vs OUTPUT VOLTAGE

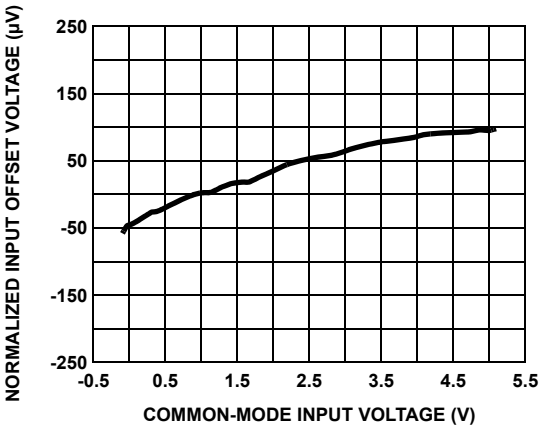


FIGURE 5. INPUT OFFSET VOLTAGE vs COMMON-MODE INPUT VOLTAGE

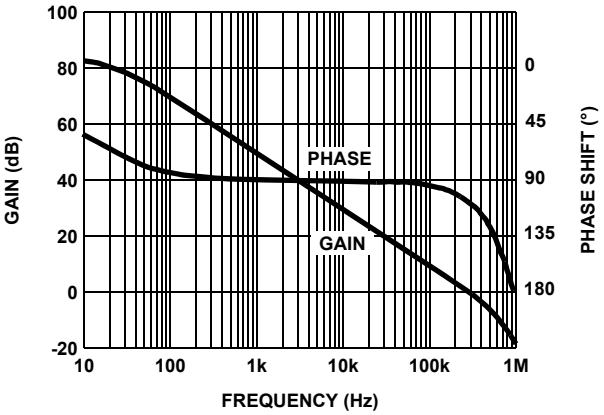


FIGURE 6. OPEN LOOP GAIN AND PHASE vs FREQUENCY ($R_L = 1k\Omega$)

Typical Performance Curves **(Continued)** V_S = ±2.5V, T_A = +25°C, Unless Otherwise Specified **(Continued)**

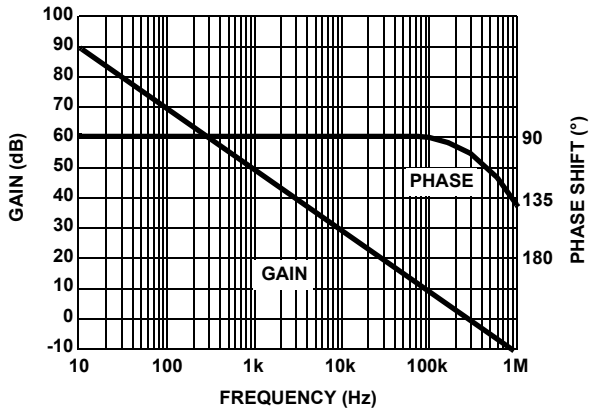


FIGURE 7. OPEN LOOP GAIN AND PHASE vs FREQUENCY (R_L = 100kΩ)

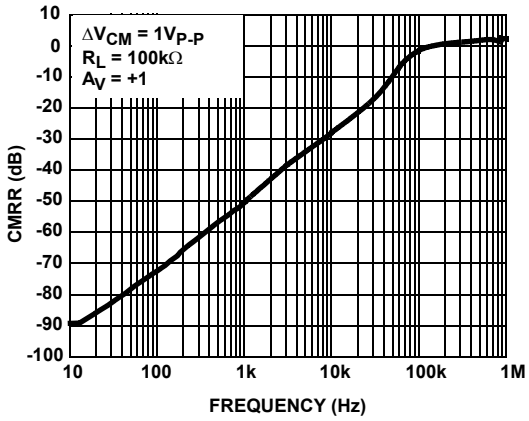


FIGURE 8. CMRR vs FREQUENCY

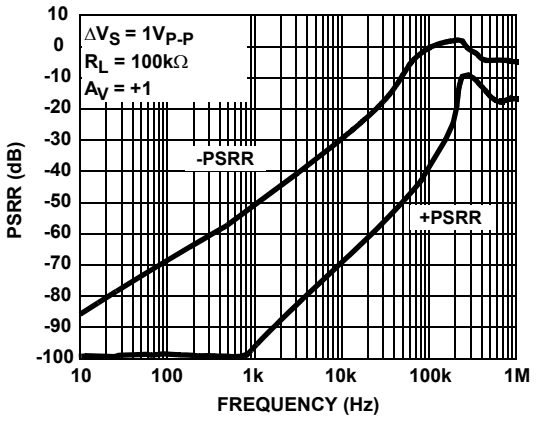


FIGURE 9. PSRR vs FREQUENCY

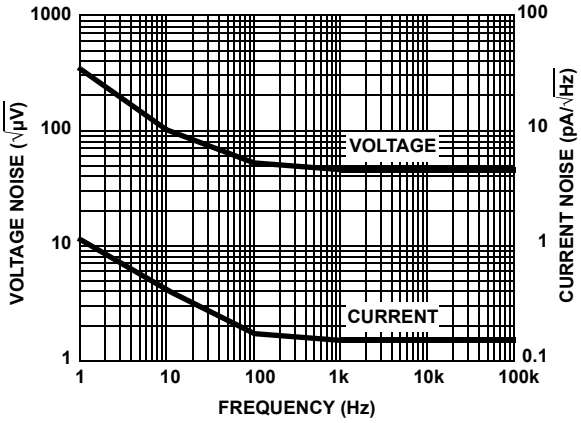


FIGURE 10. INPUT VOLTAGE AND CURRENT NOISE vs FREQUENCY

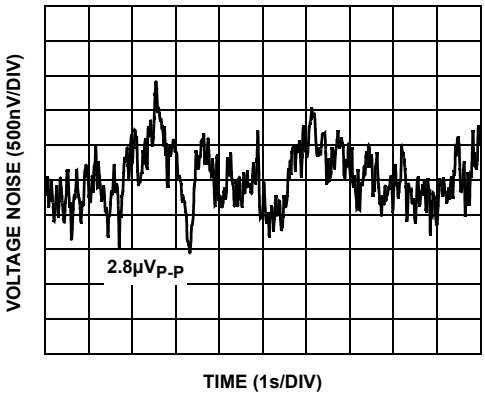


FIGURE 11. 0.1Hz TO 10Hz INPUT VOLTAGE NOISE

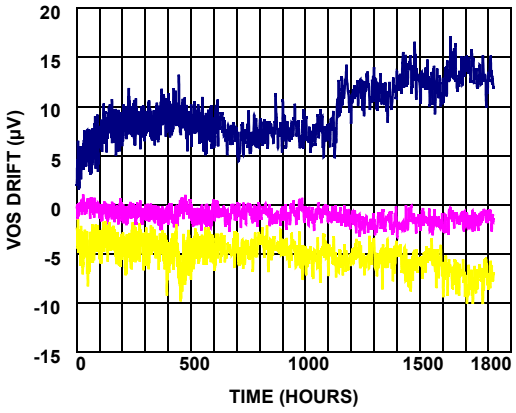


FIGURE 12. VOS DRIFT (SOT-23 PACKAGE) vs TIME

Typical Performance Curves **(Continued)** V_S = ±2.5V, T_A = +25°C, Unless Otherwise Specified **(Continued)**

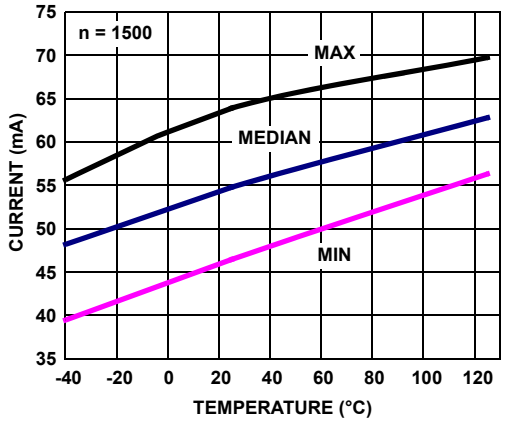


FIGURE 13. SOT-23 SUPPLY CURRENT vs TEMPERATURE, V_S = ±2.5V

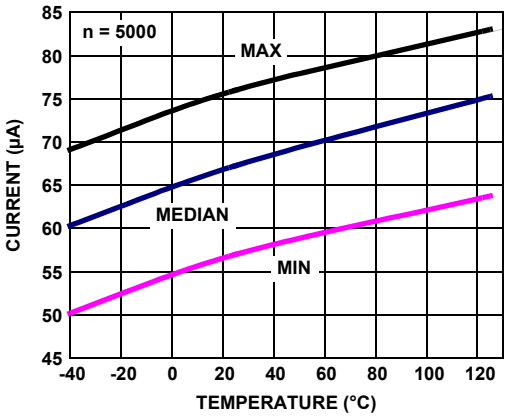


FIGURE 14. WLCSP SUPPLY CURRENT vs TEMPERATURE, V_S = ±2.5V

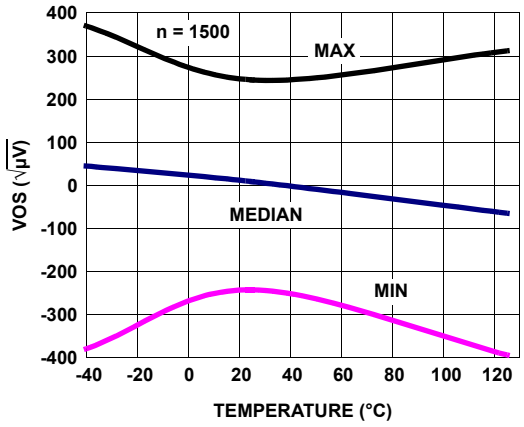


FIGURE 15. SOT-23 V_{OS} vs TEMPERATURE, V_S = ±2.5V

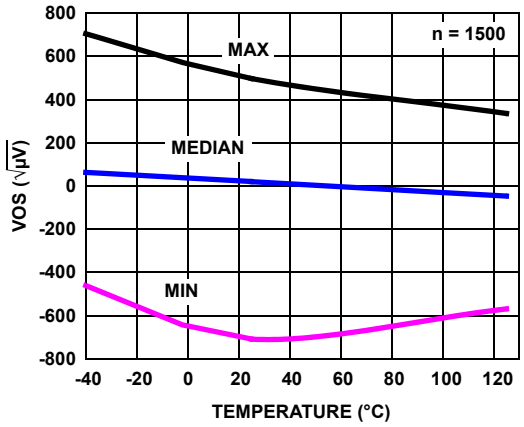


FIGURE 16. SOT-23 V_{OS} vs TEMPERATURE, V_S = ±1.2V

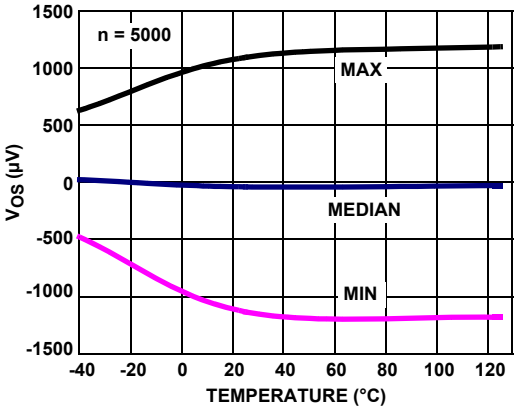


FIGURE 17. WLCSP V_{OS} vs TEMPERATURE, V_S = ±2.5V

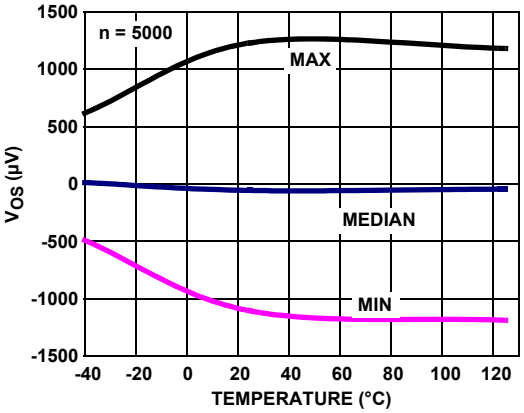


FIGURE 18. WLCSP V_{OS} vs TEMPERATURE, V_S = ±1.2V

Typical Performance Curves **(Continued)** V_S = ±2.5V, T_A = +25°C, Unless Otherwise Specified **(Continued)**

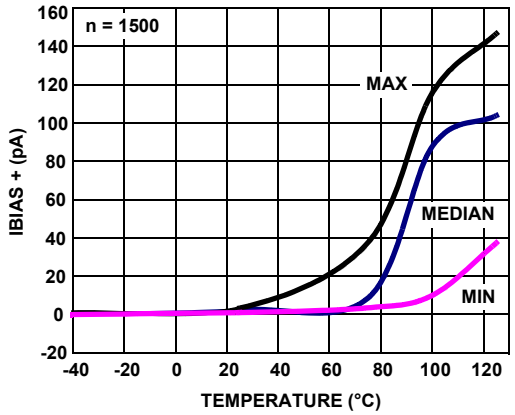


FIGURE 19. I_{BIAS+} vs TEMPERATURE, V_S = ±2.5V

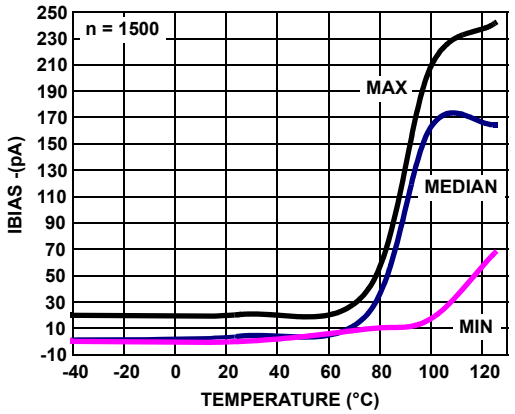


FIGURE 20. I_{BIAS-} vs TEMPERATURE, V_S = ±2.5V

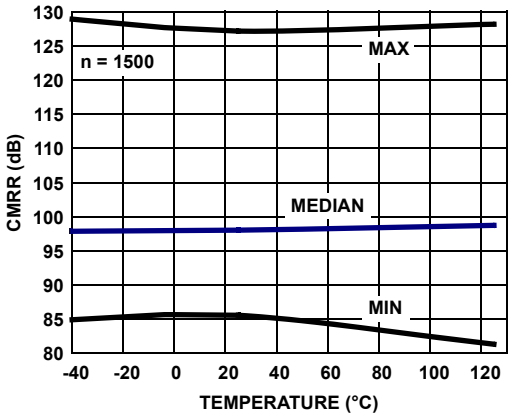


FIGURE 21. CMRR vs TEMPERATURE, V+ = ±2.5V, ±1.5V

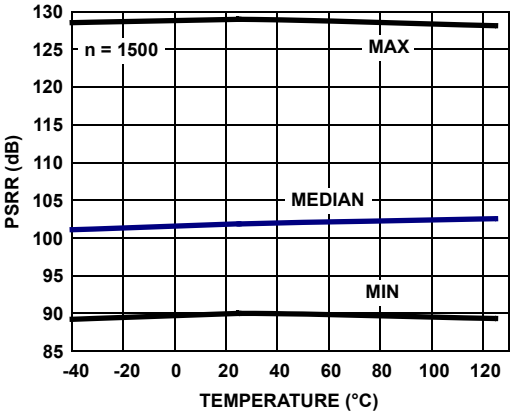


FIGURE 22. PSRR vs TEMPERATURE ±1.5V TO ±2.5V

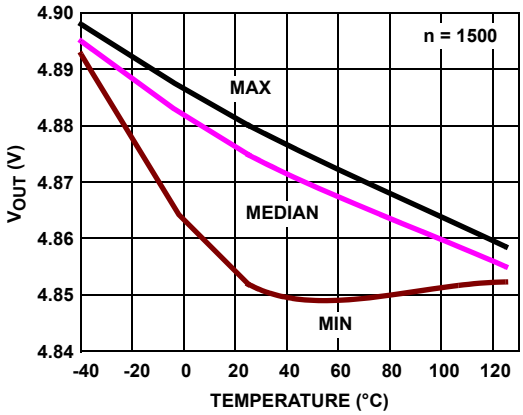


FIGURE 23. V_{OUT} HIGH vs TEMPERATURE, V_S = ±2.5V, R_L = 1k

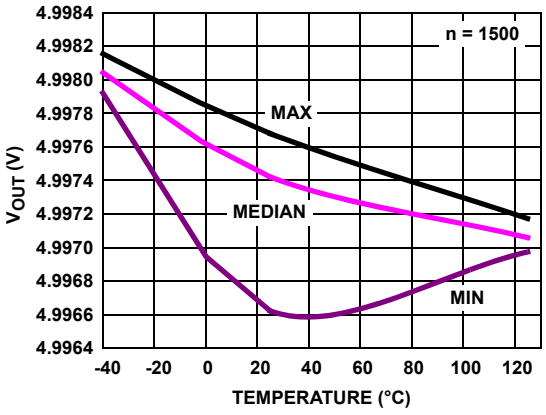


FIGURE 24. V_{OUT} HIGH vs TEMPERATURE, V_S = ±2.5V, R_L = 100k

Typical Performance Curves **(Continued)** V_S = ±2.5V, T_A = +25°C, Unless Otherwise Specified **(Continued)**

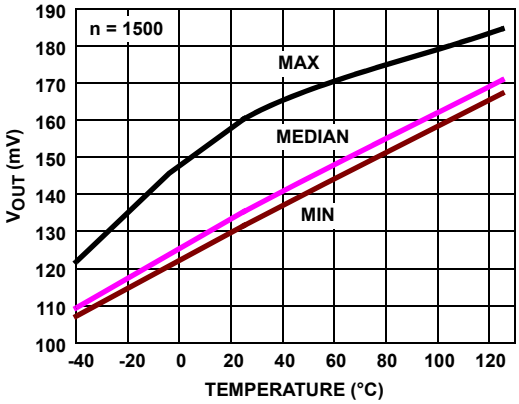


FIGURE 25. V_{OUT} LOW vs TEMPERATURE, V_S = ±2.5V, R_L = 1k

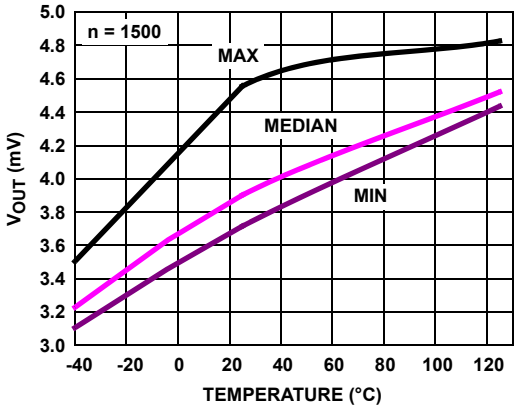


FIGURE 26. V_{OUT} LOW vs TEMPERATURE, V_S = ±2.5V, R_L = 100k

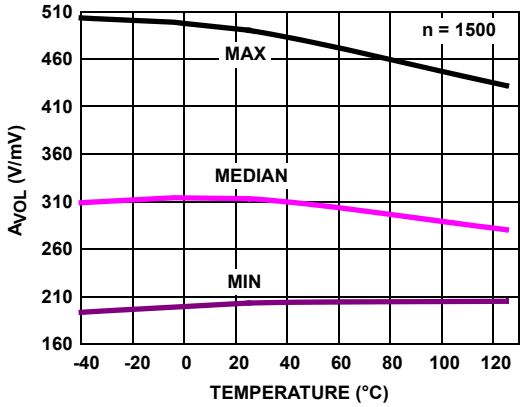
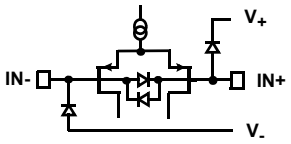


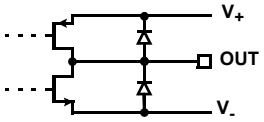
FIGURE 27. A_{VOL} vs TEMPERATURE, R_L = 100k, V_O = ±2V @ V_S = ±2.5V

Pin Descriptions

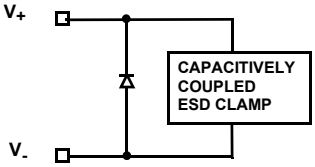
8 LD SOIC PIN NUMBER	SOT-23 PIN NUMBER	6 Ld WLCSP PIN NUMBER	PIN NAME	EQUIVALENT CIRCUIT	DESCRIPTION
1, 5			DNC		Do Not Connect; Internal connection - Must be left floating.
2	4	C1	IN-	Circuit 1	Amplifier's inverting input
3	3	C2	IN+	Circuit 1	Amplifier's non-inverting input
4	2	B2	V-	Circuit 3	Negative power supply
8	5	A1	DNC		Do not connect. Pin must be left floating.
6	1	A2	OUT	Circuit 2	Amplifier's output
7	6	B1	V+	Circuit 3	Positive power supply



CIRCUIT 1



CIRCUIT 2



CIRCUIT 3

Application Information

Introduction

The EL8188 is a rail-to-rail input and output (RRIO), micro-power, precision, single supply op amp. This amplifier is designed to operate from single supply (2.4V to 5.5V) or dual supply (±1.2V to ±2.75V) while drawing only 55µA of supply current.The device achieves rail-to-rail input and output operation while eliminating the drawbacks of many conventional RRIO op amps.

Rail-to-Rail Input

The PFET input stage of the EL8188 has an input common-mode voltage range that includes the negative and positive supplies without introducing offset errors or degrading performance like some existing rail-to-rail input op amps. Many rail-to-rail input stages use two differential input pairs: a long-tail PNP (or PFET) and an NPN (or NFET). Severe penalties result from using this topology. As the input signal moves from one supply rail to the other, the op amp switches from one input pair to the other causing changes in input offset voltage and an undesired change in the input offset current's magnitude and polarity.

The EL8188 achieves rail-to-rail input performance without sacrificing important precision specifications and without degrading distortion performance. The EL8188's input offset voltage exhibits a smooth behavior throughout the entire common-mode input range.

Rail-to-Rail Output

A pair of complementary MOSFET devices achieves rail-to-rail output swing. The NMOS sinks current to swing the output in the negative direction, while the PMOS sources current to swing the output in the positive direction. The EL8188 with a 100kΩ load swings to within 3mV of the supply rails.

Results of Over-Driving the Output

Caution should be used when over-driving the output for long periods of time. Over-driving the output can occur in three ways:

1. The input voltage times the gain of the amplifier exceeds the supply voltage by a large value.
2. The output current required is higher than the output stage can deliver.
3. Operating the device in Slew Rate Limit. These conditions can result in a shift in the Input Offset Voltage (VOS) as much as 1µV/hr of exposer under these condition.

IN+ and IN- Input Protection

In addition to ESD protection diodes to each supply rail, the EL8188 has additional back-to-back protection diodes across the differential input terminals (see "Circuit 1" diagram on page 8). If the magnitude of the differential input voltage exceeds the diode's V_F, then one of these diodes will conduct. For elevated temperatures, the leakage of the protection diodes (Circuit 1 pin description table) increases, resulting in the increase in Ibias as seen in Figures 19 and 20.

Usage Implications

If the input differential voltage is expected to exceed 0.5V, an external current limiting resistor must be used to ensure the input current never exceeds 5mA. For noninverting unity gain applications the current limiting can be via a series IN+ resistor, or via a feedback resistor of appropriate value. For other gain configurations, the series IN+ resistor is the best choice, unless the feedback (R_F) and gain setting (R_G) resistors are both sufficiently large to limit the input current to 5mA.

Large differential input voltages can arise from several sources:

1) During open loop (comparator) operation. The IN+ and IN- input voltages don't track.

2) When the amplifier is disabled but an input signal is still present. An R_L or R_G to GND keeps the IN- at GND, while the varying IN+ signal creates a differential voltage. Mux Amp applications are similar, except that the active channel V_{OUT} determines the voltage on the IN- terminal.

3) When the slew rate of the input pulse is considerably faster than the op amp's slew rate. If the V_{OUT} can't keep up with the IN+ signal, a differential voltage results, and visible distortion occurs on the input and output signals. To avoid this issue, keep the input slew rate below 0.2V/µs, or use appropriate current limiting resistors.

Output Current Limiting

The EL8188 has no internal current-limiting circuitry. If the output is shorted, it is possible to exceed the "Absolute Maximum Rating" for "operating junction temperature", potentially resulting in the destruction of the device.

Power Dissipation

It is possible to exceed the +150°C maximum junction temperature (T_{JMAX}) under certain load and power-supply conditions. It is therefore important to calculate T_{JMAX} for all applications to determine if power supply voltages, load conditions, or package type need to be modified to remain in the safe operating area. These parameters are related as follows:

$$T_{JMAX} = T_{MAX} + (\theta_{JA} \times PD_{MAX}) \quad \text{(EQ. 1)}$$

where PD_{MAX} is calculated using:

$$PD_{MAX} = V_S \times I_{SMAX} + (V_S - V_{OUTMAX}) \times \frac{V_{OUTMAX}}{R_L} \quad \text{(EQ. 2)}$$

where:

- T_{MAX} = Maximum ambient temperature
- θ_{JA} = Thermal resistance of the package
- PD_{MAX} = Maximum power dissipation of the amplifier
- V_S = Supply voltage
- I_{MAX} = Maximum supply current of the amplifier
- V_{OUTMAX} = Maximum output voltage swing of the application
- R_L = Load resistance

Proper Layout Maximizes Precision

To achieve the optimum levels of high input impedance (i.e., low input currents) and low offset voltage, care should be taken in the circuit board layout. The PC board surface must remain clean and free of moisture to avoid leakage currents between adjacent traces. Surface coating of the circuit board will reduce surface moisture and provide a humidity barrier, reducing parasitic resistance on the board. When input leakage current is a paramount concern, the use of guard rings around the amplifier inputs will further reduce leakage currents. Figure 28 shows a guard ring example for a unity gain amplifier that uses the low impedance amplifier output at the same voltage as the high impedance input to eliminate surface leakage. The guard ring does not need to be a specific width, but it should form a continuous loop around both inputs. For further reduction of leakage currents, mount components to the PC board using Teflon standoffs.

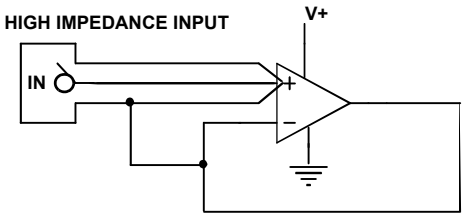


FIGURE 28. GUARD RING EXAMPLE FOR UNITY GAIN AMPLIFIER

Typical Applications

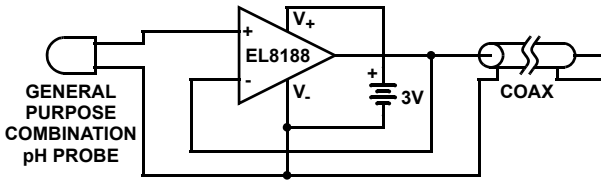


FIGURE 29. pH PROBE AMPLIFIER

A general-purpose combination pH probe has extremely high output impedance typically in the range of 10GΩ to 12GΩ. Low loss and expensive Teflon cables are often used to connect the pH probe to the meter electronics. Figure 29 details a low-cost alternative solution using the EL8188 and a low-cost coax cable. The EL8188 PMOS high impedance input senses the pH probe output signal and buffers it to drive the coax cable. Its rail-to-rail input nature also eliminates the need for a bias resistor network required by other amplifiers in the same application.

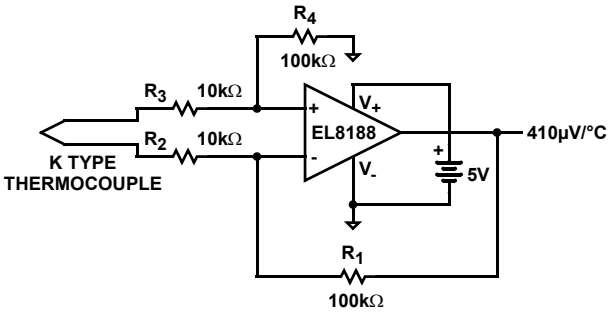


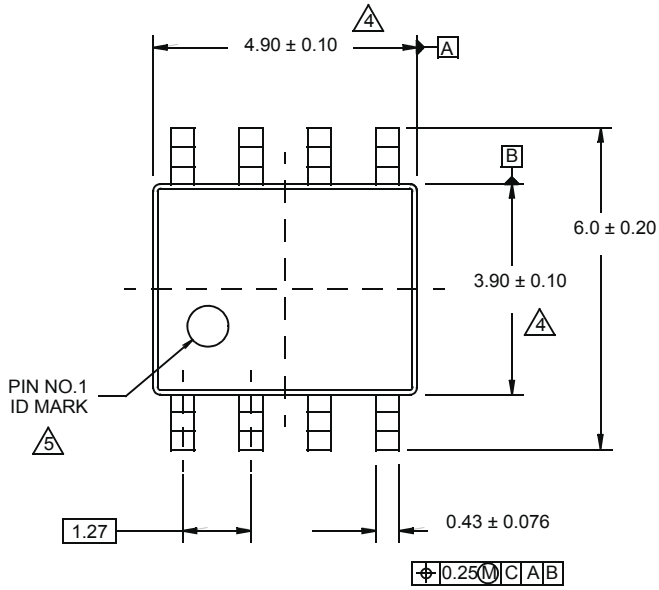
FIGURE 30. THERMOCOUPLE AMPLIFIER

Thermocouples are the most popular temperature sensing devices because of their low cost, interchangeability, and ability to measure a wide range of temperatures. In Figure 30, the EL8188 converts the differential thermocouple voltage into single-ended signal with 10X gain. The EL8188's rail-to-rail input characteristic allows the thermocouple to be biased at ground and permits the
op amp to operate from a single 5V supply.

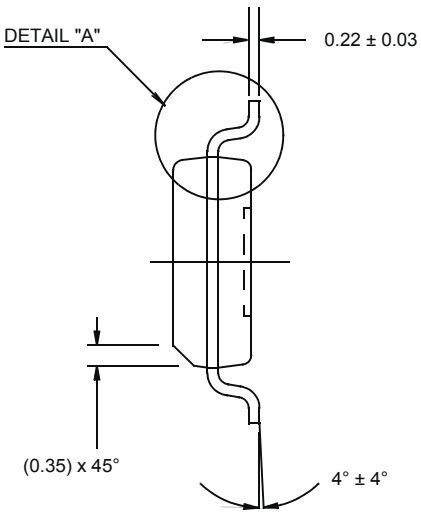
Package Outline Drawing

M8.15E

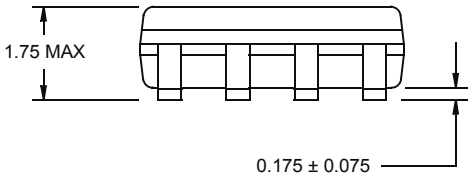
8 LEAD NARROW BODY SMALL OUTLINE PLASTIC PACKAGE
Rev 0, 08/09



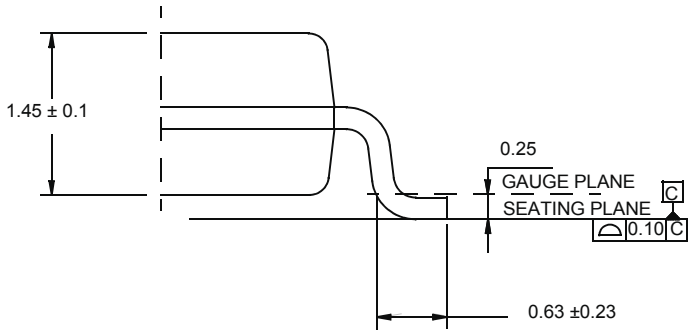
TOP VIEW



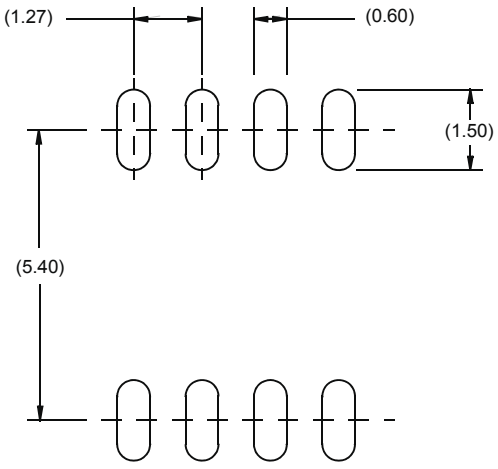
SIDE VIEW "B"



SIDE VIEW "A"



DETAIL "A"



TYPICAL RECOMMENDED LAND PATTERN

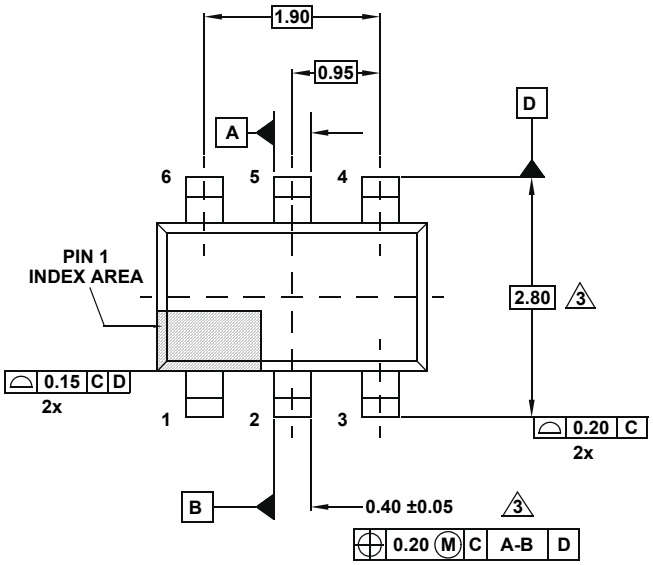
NOTES:

1. Dimensions are in millimeters.
   Dimensions in ( ) for Reference Only.
2. Dimensioning and tolerancing conform to AMSE Y14.5m-1994.
3. Unless otherwise specified, tolerance : Decimal ± 0.05
4. Dimension does not include interlead flash or protrusions.
   Interlead flash or protrusions shall not exceed 0.25mm per side.
5. The pin #1 identifier may be either a mold or mark feature.
6. Reference to JEDEC MS-012.

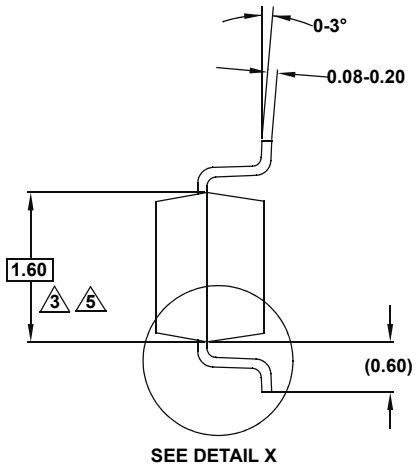
Package Outline Drawing

P6.064A

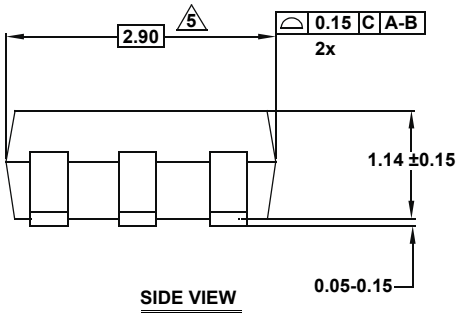
6 LEAD SMALL OUTLINE TRANSISTOR PLASTIC PACKAGE
Rev 0, 2/10



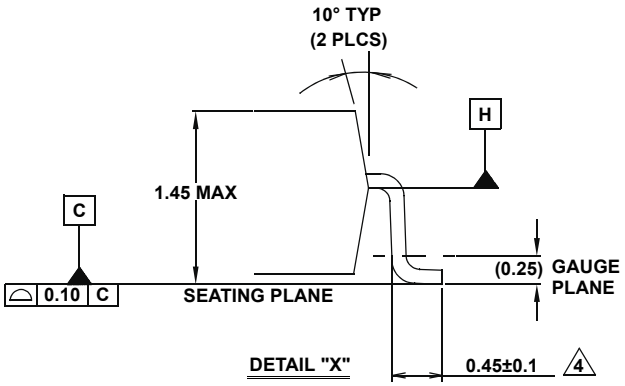
TOP VIEW



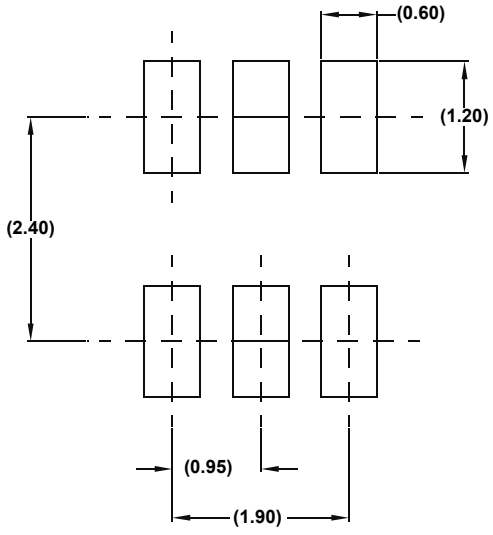
END VIEW



SIDE VIEW



DETAIL "X"

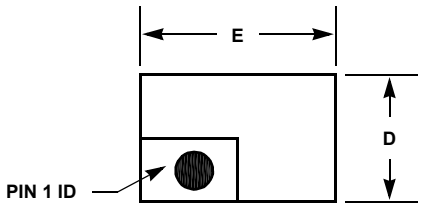


TYPICAL RECOMMENDED LAND PATTERN

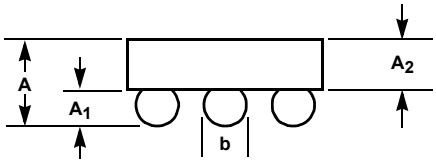
NOTES:

1. Dimensions are in millimeters.
   Dimensions in ( ) for Reference Only.
2. Dimensioning and tolerancing conform to ASME Y14.5M-1994.
3. Dimension is exclusive of mold flash, protrusions or gate burrs.
4. Foot length is measured at reference to guage plane.
5. This dimension is measured at Datum “H”.
6. Package conforms to JEDEC MO-178AA.

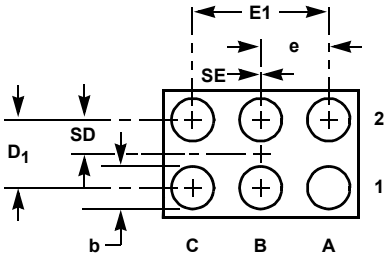
Wafer Level Chip Scale Package (WLCSP)



TOP VIEW



SIDE VIEW



BOTTOM VIEW

W3x2.6C

3x2 ARRAY 6 BALL WAFER LEVEL CHIP SCALE PACKAGE

SYMBOL	MILLIMETERS
A	0.51 Min, 0.55 Max
A_1	0.225 ±0.015
A_2	0.305 ±0.013
b	Φ0.323 ±0.025
D	0.955 ±0.020
D_1	0.50 BASIC
E	1.455 ±0.020
E_1	1.00 BASIC
e	0.50 BASIC
SD	0.25 BASIC
SE	0.00 BASIC

Rev. 3 03/08

NOTES:

1. All dimensions are in millimeters.